BNL-111783-2016-IR
Informal Report

METEOROLOGICAL SERVICES

ANNUAL DATA REPORT FOR 2015

John Heiser & Scott Smith
Meteorological Services
Environmental & Climate Science Department
Brookhaven National Laboratory

Informal Report

January 2016

Environmental & Climate Science Department

Brookhaven National Laboratory
P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Purpose

This document presents the meteorological data collected at Brookhaven National Laboratory (BNL) by Meteorological Services (Met Services) for the calendar year 2015. The purpose is to publicize the data sets available to emergency personnel, researchers and facility operations. Met services has been collecting data at BNL since 1949. Data from 1994 to the present is available in digital format. Data is presented in monthly plots of one-minute data. This allows the reader the ability to peruse the data for trends or anomalies that may be of interest to them. Full data sets are available to BNL personnel and to a limited degree outside researchers. The full data sets allow plotting the data on expanded time scales to obtain greater details (e.g., daily solar variability, inversions, etc.).

Background

Meteorological Services (Met Services) is responsible for the maintenance, calibration, data collection and data archiving for the weather instrumentation network at Brookhaven National Laboratory. Measurements include wind speed, wind direction, temperature, rainfall, barometric pressure and relative humidity. Wind speed, wind direction and temperature are measured at 85 meters, 50 meters and at 10 meters. Rainfall, relative humidity, temperature and barometric pressure are taken at the 2 meter height. This critical data set is used for NEPA calculations, for emergency planning and operations (i.e., chemical spill or accidental release) and general research. In addition to the weather sensors, Met Services maintains a solar resource base station which measures solar radiation at BNL. Instruments include Solys-2, sun tracker equipped with a pyrheliometer (direct normal incidence radiation), a ventilated, shaded pyrgeometer (downwards long-wave, infrared radiation), a ventilated, shaded, research grade pyranometer (diffuse solar radiation) and a ventilated, unshaded, research grade pyranometer (global solar radiation). The base station also has a Sky Imager for cloud imaging and SP-Lite2 pyranometers (in-plane and horizontal) that replicate the research array sensors at the Long Island Solar Farm (LISF) and the Northeast Solar Energy Research Center (NSERC).

Meteorological data is also presented in real time via a webserver at http://wx1.bnl.gov. Current weather parameters are posted here. Using buttons and pull-down menus the user has a method to graph the data from several hours to several days for the past 12 months (http://wx1.bnl.gov/graph.html) and to see information on stability class (http://wx1.bnl.gov/stability.php). Graphing includes barometric pressure, temperature, wind speed, wind direction, wind gust, humidity, precipitation and solar radiation. To facilitate safe climbing of the 85-meter met tower, we also maintain a webpage with a graphical presentation of wind speed and wind gust for the past four hours (http://wx1.bnl.gov/towerclimb.html). This page allows workers to see the wind conditions on the tower and thereby, determine if the winds are within BNL's safe parameters (25 mph or less at the time of a climb). The page reports data from both sets of sensors on the tower, giving redundancy and a better safety margin. In addition, Met Services has a QA/QC webpage that shows all sensors over the past 24 hours (http://wx1.bnl.gov/graphpage.html). This allows us to periodically (daily or greater) check the sensors and see that they are within reasonable limits and agreement.

Site

Weather conditions at the BNL site have been recorded since August 1948. BNL is broadly influenced by continental and maritime weather systems. Locally, the major weather systems are modified by the Long Island Sound, the Atlantic Ocean and associated bays, which influence wind directions and humidity, and provide a moderating influence on extreme summer and winter temperatures.

BNL is a well-ventilated site, with an annual distribution of wind direction reflecting a predominance of westerly components. Prevailing winds are from the south-southwest during the summer, from the west-northwest during the winter, and about equally from these two directions during the spring and fall.

Instrument Towers

85-meter Tower

The 85-meter (280-ft.) meteorological tower was placed in operation in May 1981 to replace the former and original "Ace Tower" used in the first 30 operational years at BNL. The tower (Fig. 1) is located in an open field west of the majority of the Brookhaven building complex at latitude 40°52’14.84”N and longitude 72°53’20.05”W and its base is 24 m (80 ft.) above sea level and is referred to as "Tower Ten". In this document, the primary, tall tower will be called, the main or 85-meter tower to avoid confusion with the smaller, secondary 10-meter tower also in operation at the Met field.

The main tower is made of galvanized steel, is triangular in shape with 3 ft. sides and has 3 sets of 8 guy wires to keep it upright. It has an inside ladder for climbing, and two working levels with small platforms. It is difficult to mount booms and equipment or to work on this tower. Special safety belts and harnesses are required when climbing, maintaining or calibrating equipment on this tower. Sensor location names designate the approximate height of the sensors above the ground. At each location there are fully redundant sensor sets. Each set is independent of the other with unique data loggers and sensors. At locations M85 and M50 instrumentation includes; R.M. Young model 5106 Marine grade wind monitors for wind speed and direction and R.M. Young model 41342VC temperature probes. The temperature probes are protected by naturally aspirated radiation shields. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

10-meter Tower

A foldable-mast, ten-meter tower is located approximately at the center of the Meteorological field. Again, fully redundant sensor sets are present. Instrumentation includes R.M. Young model 5106 Marine grade wind monitors for wind speed and direction and R.M. Young model 41342VC temperature probes. The temperature probes are protected by naturally aspirated radiation shields. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

2-meter pole

At two meters (located near the 10-meter tower) sensors include; Campbell/Rotonic HC2-S3 temperature and relative humidity probes and R.M. Young model 61302V barometric pressure sensors. The T/RH probes have actively aspirated (powered fan) shields. Data collection is via Campbell CR1000 data loggers and transmitted to the main data computer via Campbell model RF401, 900-MHz Spread-Spectrum Radio modems.

Two tipping-bucket rain gauges (Novalynx model 260-2501) are maintained on the roof of building 490D. This location was chosen for available 115VAC for the heaters in the gauges required for winter use. Data collection is via Campbell CR1000 data loggers with direct network connections.

Solar Base Station

Met Services maintains a platform on the roof of building 490D. This platform is used for testing of sensors and also houses the LISF research projects base station for solar irradiance measurements. Instrumentation at this location includes; a Kipp and Zonen model Solys-2 suntracker equipped with a shaded Kipp and Zonen model CGR-4 pyrgeometer for long-wave, far infrared radiation, a Kipp and Zonen model CHP-1 pyrheliometer to measure direct normal indicent radiation and two Kipp and Zonen CMP-22 research grade pyranometers, one shaded and one unshaded, to record diffuse and global radiation. BNL is also home to the Long Island Solar Farm (LISF) and the Northeast Solar Energy Research Center (NSERC) where we maintain a arrays of sensors including pyranometers. As a reference for the LISF sensor array, two Kipp and Zonen model SP-lite2 pyranometers are maintained, one in-plane (aka tilted global radiation) at the 27° angle of inclination for the panels at the LISF and one horizontal (global radiation). Similarly, for the NSERC sensor array, two SP-lite2 pyranometers are maintained, one in-plane at the 23° angle of inclination for the panels at the NSERC and a mating horizontally aligned unit. Data collection is via a Campbell CR3000 data loggers directly connected to the network. Additionally a Total Sky Imager (TSI) is mounted on the platform and is directly connected to the network. Images from the TSI are available to BNL users.

Calibrations

All sensors are calibrated annually in accordance to the BNL Meteorological Instrument Network Calibration Plan (Heiser 2012). Where an instrument is sent off site for calibration a duplicate calibrated unit is available for replacement.

The calibration and maintenance frequency is based on the following hierarchy:

1. Manufacturers recommendation as stated in the instruments Operation Manual or Owner's Instruction Manual.

2. Manufacturers recommendation as stated in other communications such as a memorandum, email, or documented phone conversation.

3. Other engineering or scientific standards specifically referring to a particular type of instrument (e.g., American Nuclear Society, American National Standards Institute).

4. Met Services determination of calibration needs based on experience with the equipment or recommendations from other sources.

Calibration certificates are required from the companies performing calibrations and these certificates are compiled in the Instrument Calibration Notebooks. For sensors that are calibrated on site or in-situ by BNL personnel, the data taken is recorded on instrument specific data sheets and the sheets are compiled into the Instrument Calibration Notebooks. The original notebooks are maintained by the head of Met Services. Additionally, an electronic master list of equipment and the current status of each instruments calibration along with calibration coefficients is maintained on the Met Services master computer with copies available from the Head of Met Services and the Operations Officer.

Data Sets and Data Availability

Meteorological sensors are checked daily and duplicate sensors inter-compared. On a monthly basis the data goes through a QA/QC process to help eliminate bad records and correct or remove any erroneous values. The post processing of the data involves visually analyzing the data in eight day increments looking for bad data points. MatLab, data analysis software, is used for this purpose. Using a series of scripts it is relatively easy to remove single or multiple data points. Once the bad data is removed the operator can chose to fill in the missing points by interpolation or leave the data as "missing". The data is then saved to a file. This data is then backed up along with the raw unedited data. In addition to this we also do a comparative analysis on the "A" and "B" datasets to insure precision between the two independent systems. Data reported is generally taken from the "A" side sensors with "B" side sensors serving as backups. If data checks show the A sensors to be out of service, out of spec or questionable the data is replaced by B sensor data until the A sensor is replaced/repaired.

After the editing is complete, daily and hourly averages and sums are calculated and saved to files to be disseminated upon request. The averages are then added to a spreadsheet that includes all the past data collected here at BNL, going back as far as 1949. See; http://www.bnl.gov/weather/MonthlyClimatology.asp

Currently data is available as monthly, daily, hourly and one minute averages. Subsets of the main data set are also available. Most requests are for a small, specific time frame, which can usually be produced in one to two days.

Meteorological Data Recovery for 2015

For the year, Met Services had a 100 percent record retrieval rate, collecting all of the 525,600 records. This equates to a total of 10,512,000 fields of data that could have been collected for the year. During the course of the year there were two significant failures (greater than one hour) that resulted in a total of ≈19 hours of partial data loss. Instrumentation on the main tower was not collecting data for 1 hour, 50 minutes during the period from May 12th at 0836 until May 12th at 1025. There was another period where instruments on the main tower were not collecting data for 17 hours and 38 minutes, this was between Jul. 21st at 1630 and Jul. 22nd at 1018. In addition to these major outages there were a number of smaller events that amounted to usually less than one hour of data loss. Of the 10,512,000 data points available for collection the system failed to record 16,526 data points. This equates to a loss of just 0.16% of the total amount of data available for recording or 99.84% data recovery for the year.

For the solar base station system there was one significant failure in 2015 that lasted 61 minutes. It occurred on April 9th from 1124 hours to 1224 hours. There were a few short time losses that totaled 945 missing data points out of a possible 4,204,800 for the year which represents a 99.98% data recovery rate for the year.

2015 Meteorological Data

Table 1. 2015 Extremes and Totals[a]

Highest Temperature	33.9 C° September 8th
Lowest Temperature	-21.8 C° February 24th
Average Yearly Temperature	10.8 C°
Annual Precipitation	39.37"
Maximum Monthly Precipitation	5.87" in March
Minimum Monthly Precipitation	0.53″ in May
Maximum Daily Precipitation	1.83″ on October 2nd
Maximum Hourly Rainfall	0.83″ on September 30th from 0200hrs to 0300hrs
Maximum Wind Speed (85 meters)	21.4 m/s (47.9 mph) February 15th
Maximum Wind Gust (85 meters)	27.1 m/s (60.6 mph) April 20th
Maximum Wind Speed (10 meters)	10.5 m/s (23.5 mph) March 2nd
Maximum Wind Gust (10 meters)	19.1 m/s (42.7 mph) January 31st
Maximum Barometric Pressure	1038.9 mbar November 26th
Lowest Barometric Pressure	986.2 mbar January 24th
Lowest Relative Humidity	14% April 15th
Heating Degree Days	5784.0
Cooling Degree Days	807.9
Average Daily Irradiance	171 W/m^2

a = Measurements taken at the 2 meter height unless otherwise noted.

Air Temperature

Temperature is measured using platinum resistance thermometers (PRT) at 2-meters (Campbell HC2-S3), 10-meters (R.M. Young 41342VC), 50-meters (R.M. Young 41342VC) and 85-meters (R.M. Young 41342VC) at the locations described above.

All probes are calibrated internally by BNL staff. A high quality constant temperature bath along with a reference PRT are used to perform a comparison calibration curve. The PRT is calibrated off-site to NIST standards. Met Services uses the comparison method of calibrating temperature sensors. The thermometer is calibrated by comparison with a reference or standard thermometer in a thermally stabilized bath. The procedure uses a four point calibration consisting of -10°C, 5°C, 20°C and 35°C. ANSI/ANS-3.11-2005 lists the air temperature minimum accuracy of 0.5°C and a minimum resolution of 0.1°C. For stability class determinations using vertical temperature differences the requirements are; a minimum accuracy of 0.1°C and a minimum resolution of 0.01°C. Meteorological data is held to the later, more stringent requirement

For platinum resistance probes and modest accuracy applications the resistance-temperature relationship can be approximated by the Callendar-Van Dusen equation as:

$R(t) = R(0)[1 + At + Bt2 + C(t-100)t3]$

Where:
t = temperature (°C),
R(t) = resistance at temperature t,
R(0) = resistance at 0°C,
and using ASTM 1137 and IEC 60751 coefficient values for a standard 100 ohm sensor having an alpha value of 0.00385;
A = 3.9083 x 10-3 (°C-1),
B = -5.775 x 10-7(°C-2) and
C = -4.183 x 10-12 (°C-4) [for temperatures above 0°C, C = 0]

Within the temperature range of BNLs minimum observed temperature (-31°C) and maximum observed temperature (38°C), the B and C coefficients can be ignored and approximated as zero and;

$R(t) = R(0) + R(0)•At$

Daily average temperature for the year is presented in Figure 1. Daily minimums and maximums for the year are shown in Figure 2. Table 2 summarizes the 2 meter monthly average daily temperatures, average daily minimum and maximum temperatures and monthly extreme high and lows. Figure 3 depicts the 2012 monthly temperature means and compares them to historic means. Table 3, 4 and 5 lists the historic monthly average, average monthly maximum and average monthly minimum temperatures from 1949 to 2012. Monthly data plots of 1-minute data at the four met field measurement locations are presented in Figures 4 through 15.

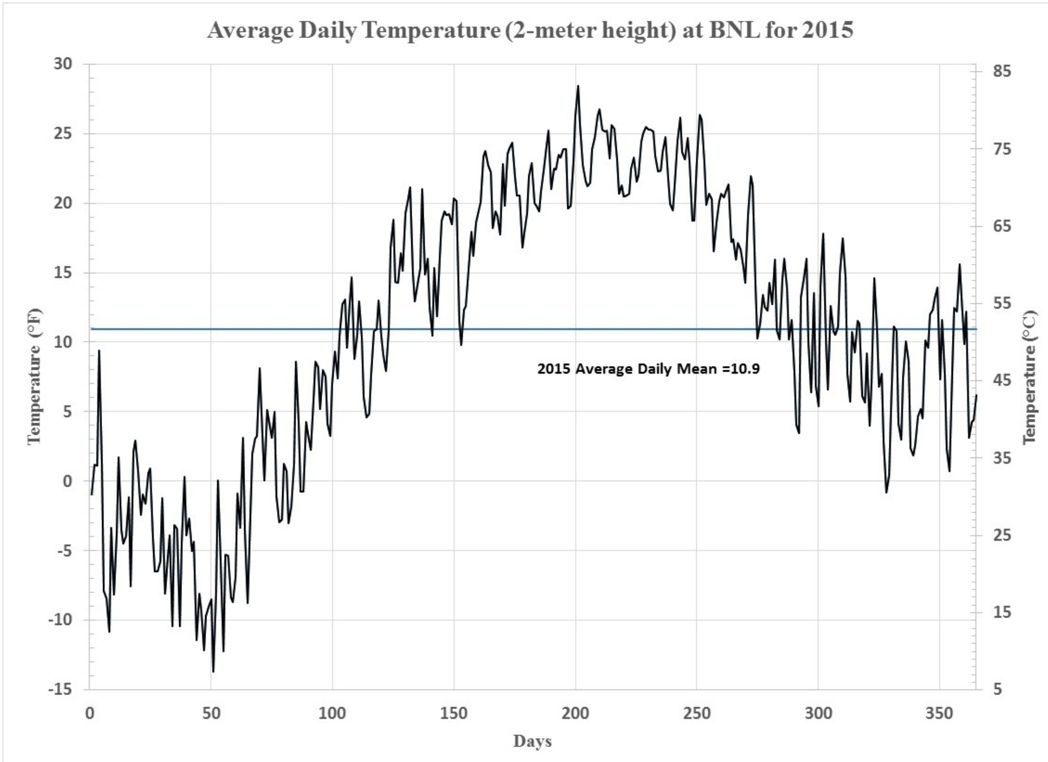

Figure 1 Average Daily Temperature taken at the 2 meter height at BNL for 2015

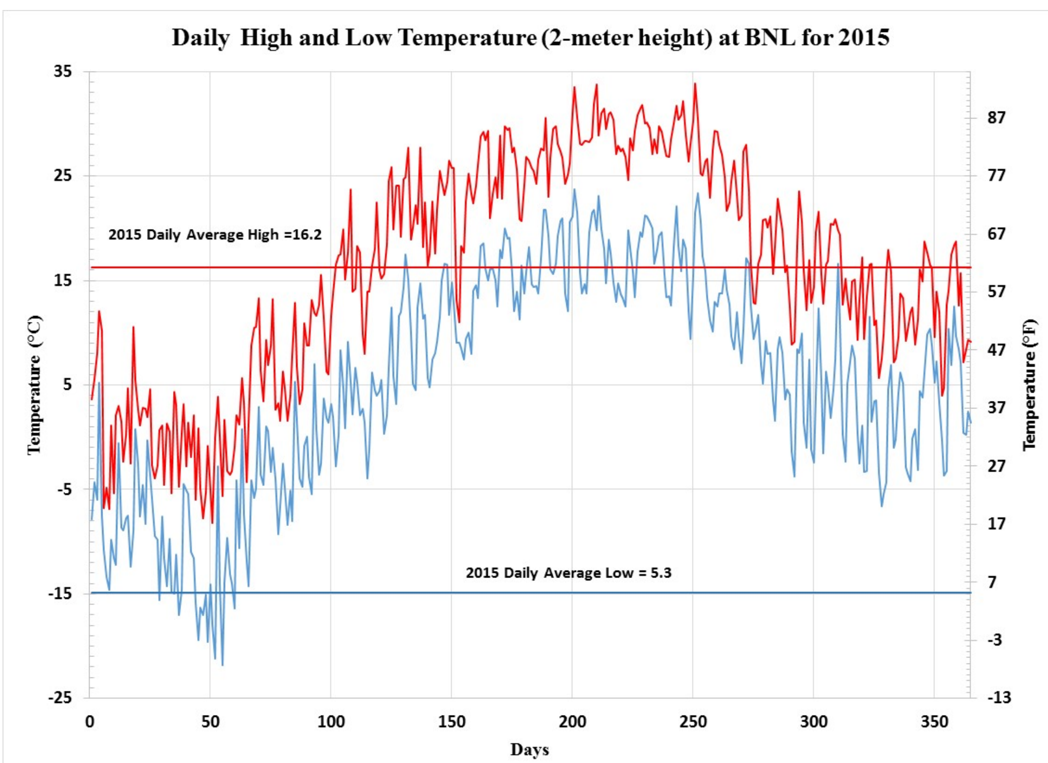

Figure 2 Daily Minimums and Maximums in Temperature taken at the 2 meter height at BNL for 2015

Table 2. Monthly Temperature Summary

Month	2015 Temperatures (°C) @ 2 meters						
	Average			Extremes			
	Daily Mean	Daily High	Daily Low	High	Date	Low	Date
Jan	-2.6	1.4	-7.5	12.1	Jan 4	-15.6	Jan 29
Feb	-6.9	-1.6	-13.6	4.3	Feb 4	-21.8	Feb 24
Mar	0.7	5.8	-4.4	13.3	Mar 11	-16.4	Mar 1
Apr	8.7	14.4	2.1	23.7	Apr 18	-5.5	Apr 2
May	16.0	22.1	10.0	27.7	May 17	0.3	May 2
Jun	19.1	24.2	14.1	29.8	Jun 21	7.4	Jun 4
Jul	23.1	28.1	18.1	33.8	Jul 29	12.1	Jul 17
Aug	23.1	29.0	17.0	31.8	Aug 17	12.5	Aug 10
Sep	20.2	26.8	14.3	33.9	Sep 8	7.1	Sep 27
Oct	11.4	16.9	5.5	23.5	Oct 21	-3.8	Oct 19
Nov	8.6	14.0	2.7	20.9	Nov 5	-6.6	Nov 24
Dec	8.1	12.5	3.7	18.7	Dec 12	-4.2	Dec 6

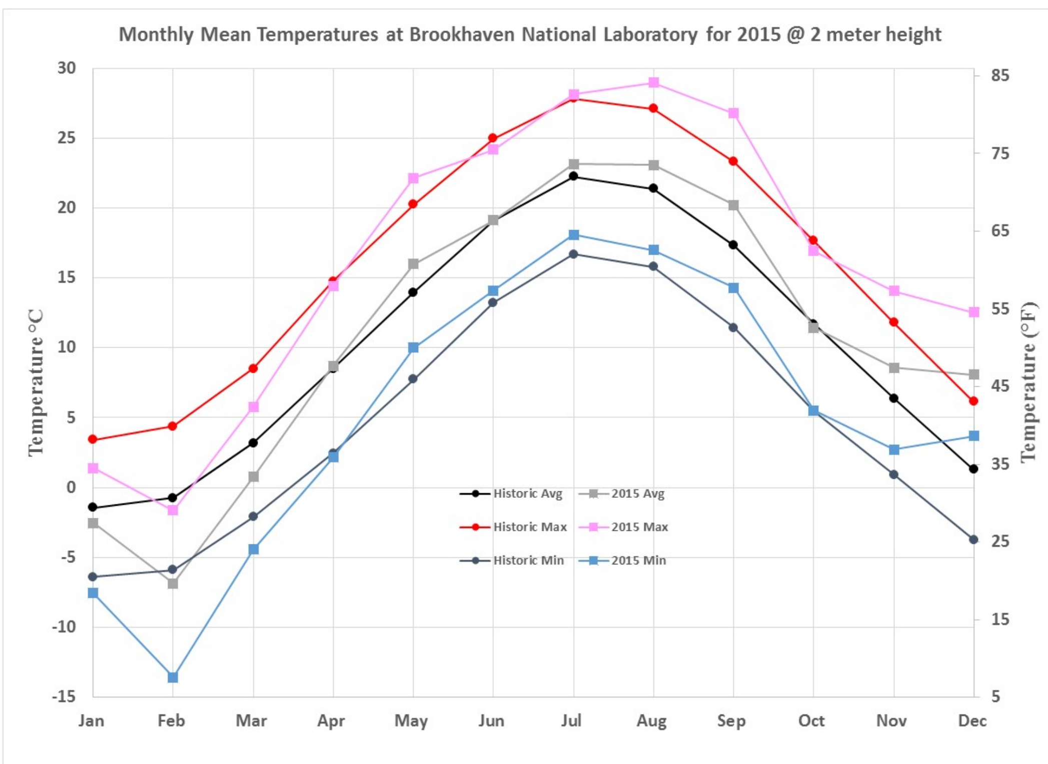

Figure 3 Monthly Mean Temperatures (°C) at Brookhaven National Laboratory for 2015

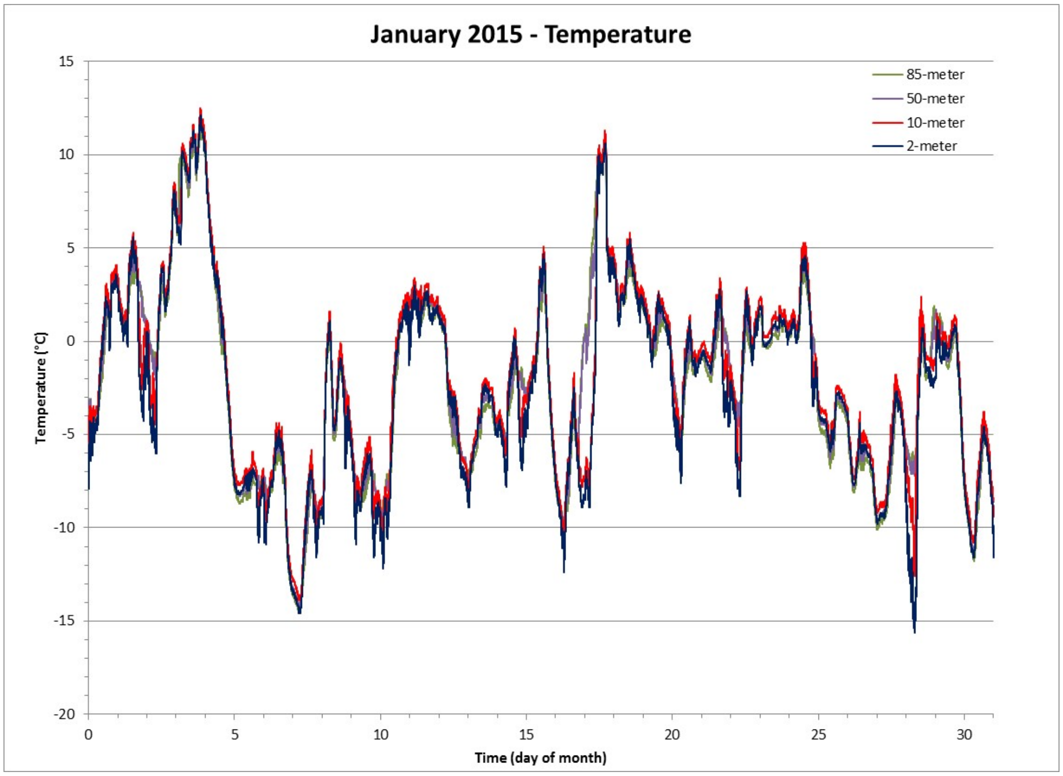

Figure 4 Air Temperature for the Month of January 2015

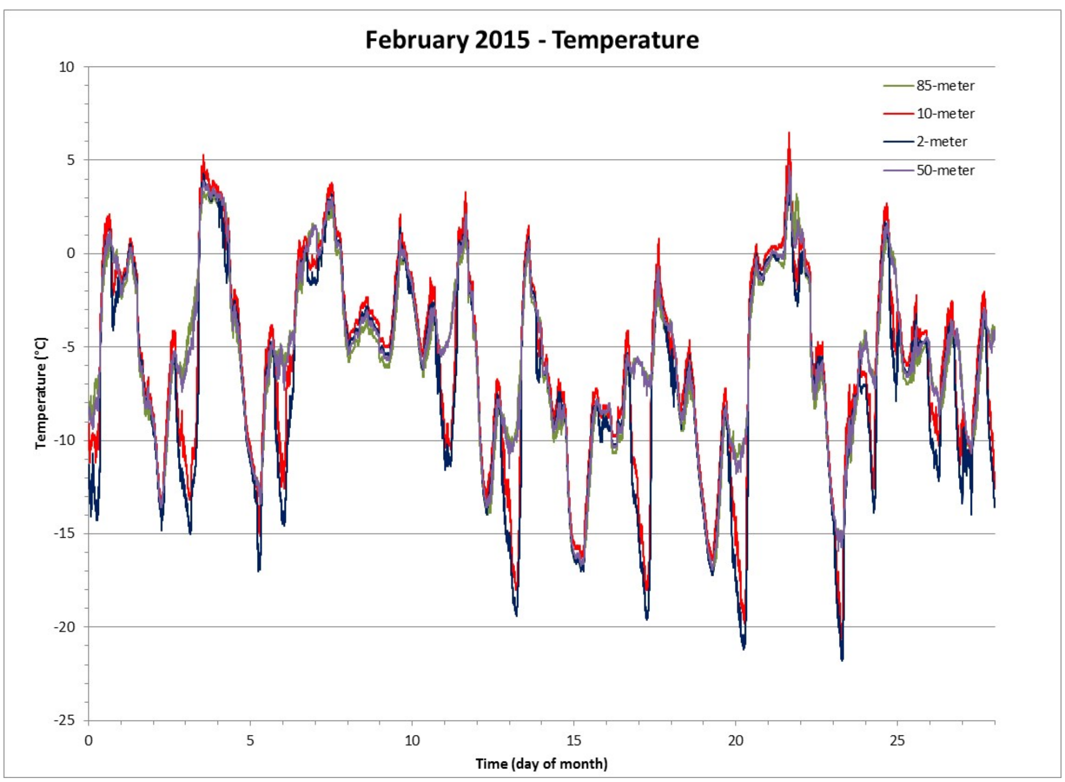

Figure 5 Air Temperature for the Month of February 2015

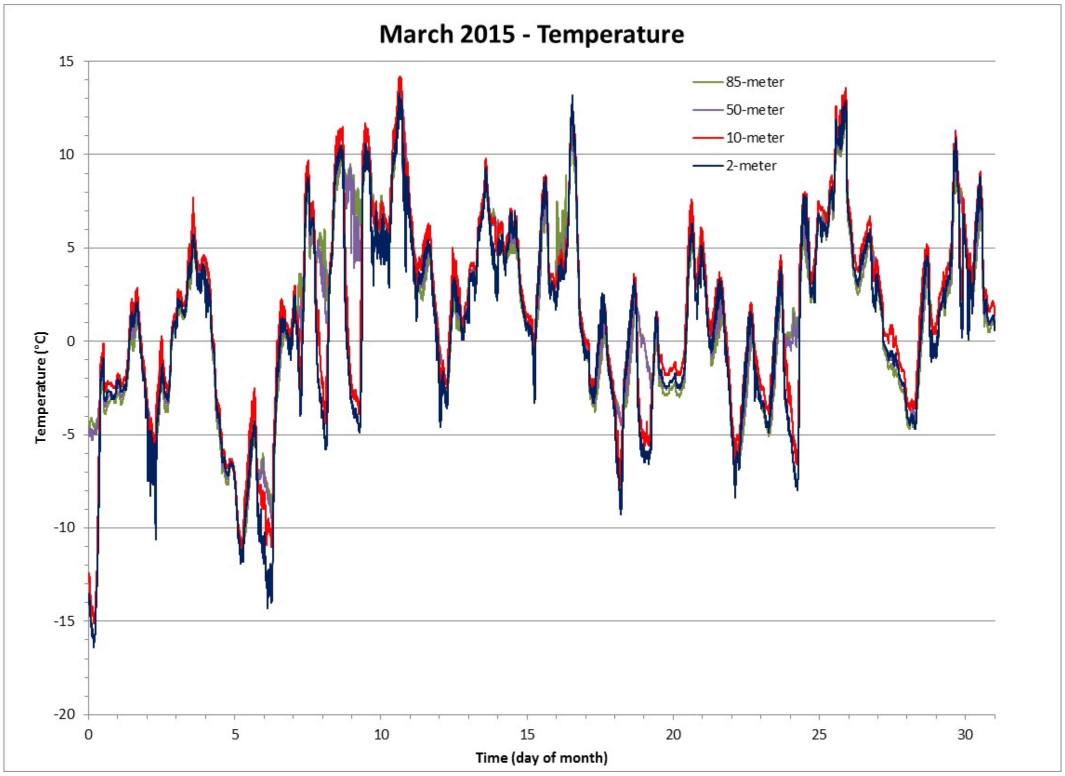

Figure 6 Air Temperature for the Month of March 2015

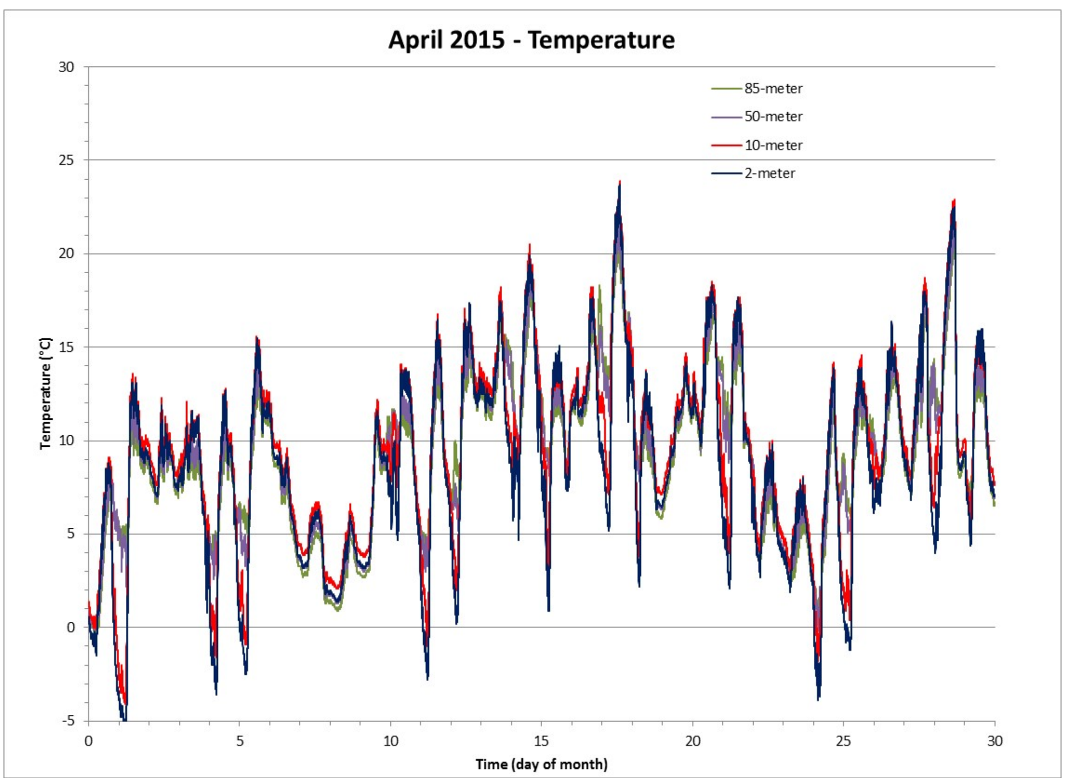

Figure 7 Air Temperature for the Month of April 2015

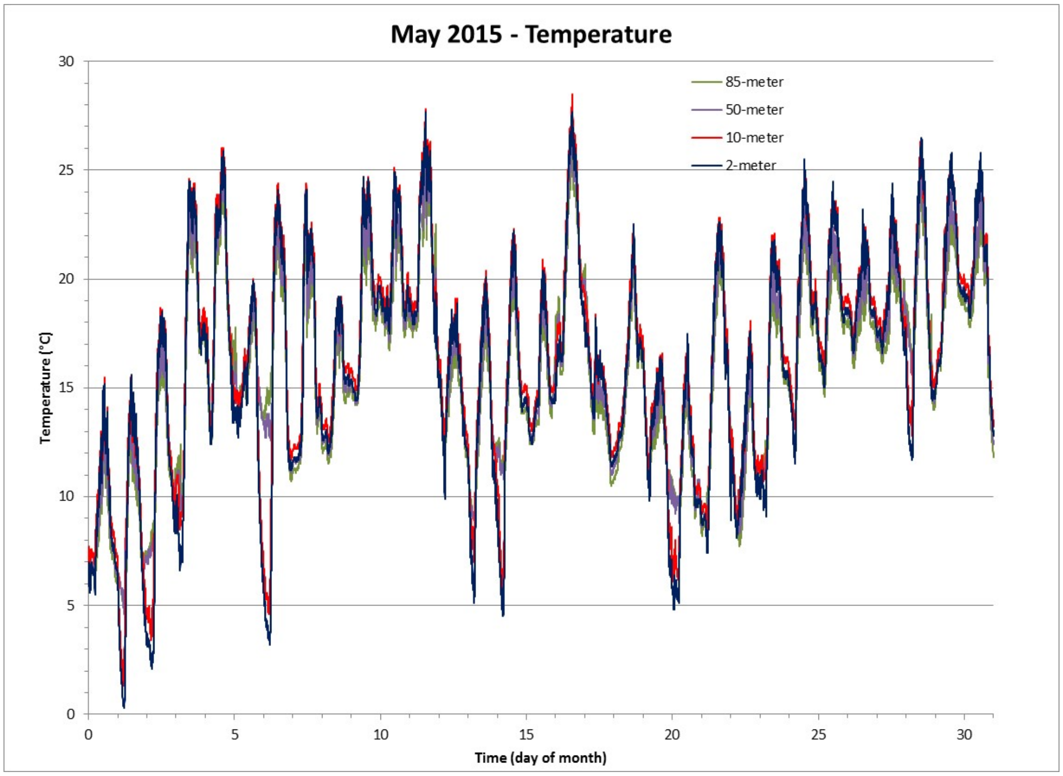

Figure 8 Air Temperature for the Month of May 2015

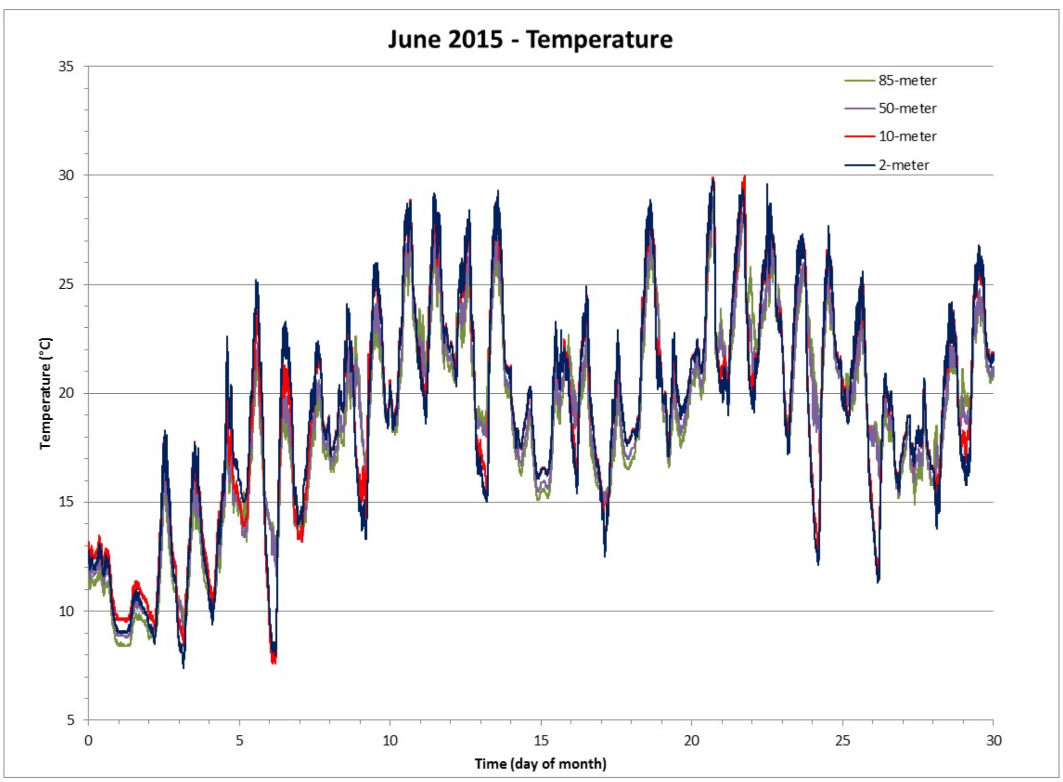

Figure 9 Air Temperature for the Month of June 2015

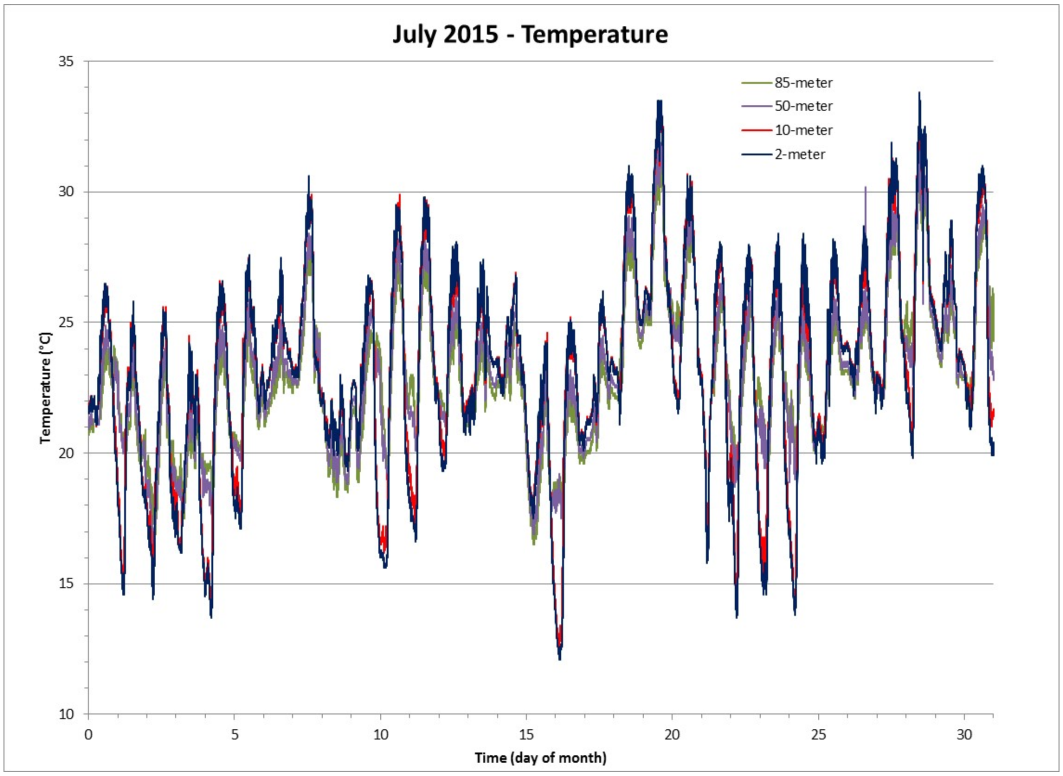

Figure 10 Air Temperature for the Month of July 2015

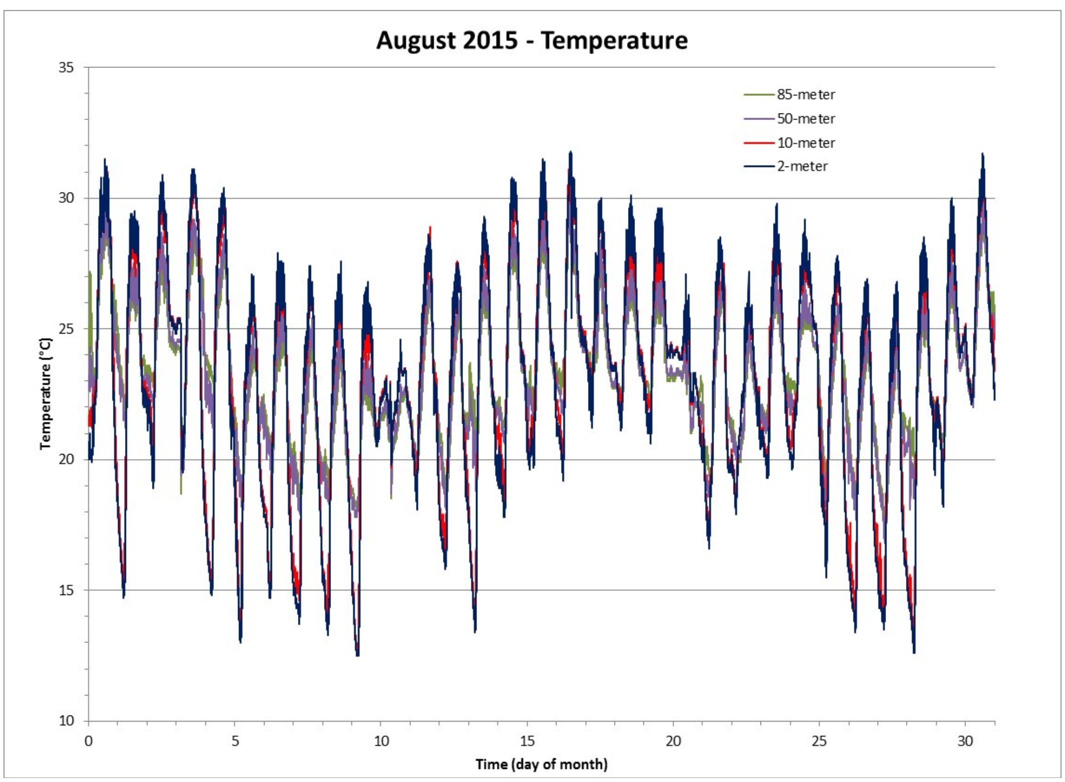

Figure 11 Air Temperature for the Month of August 2015

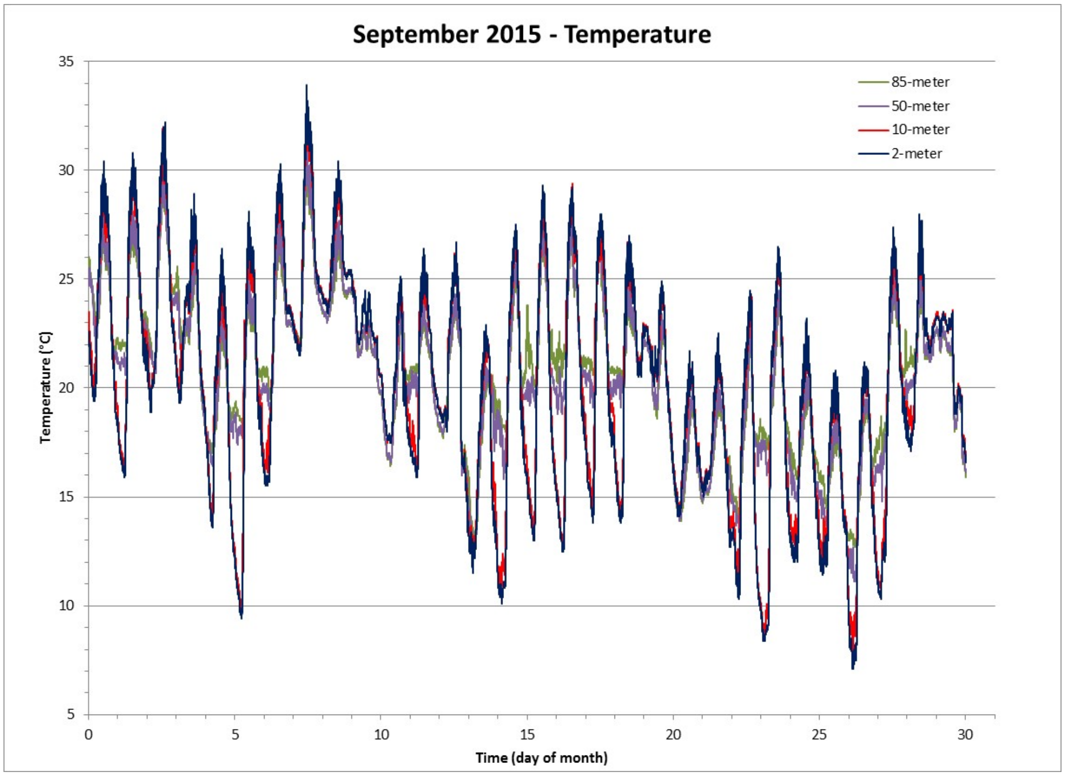

Figure 12 Air Temperature for the Month of September 2015

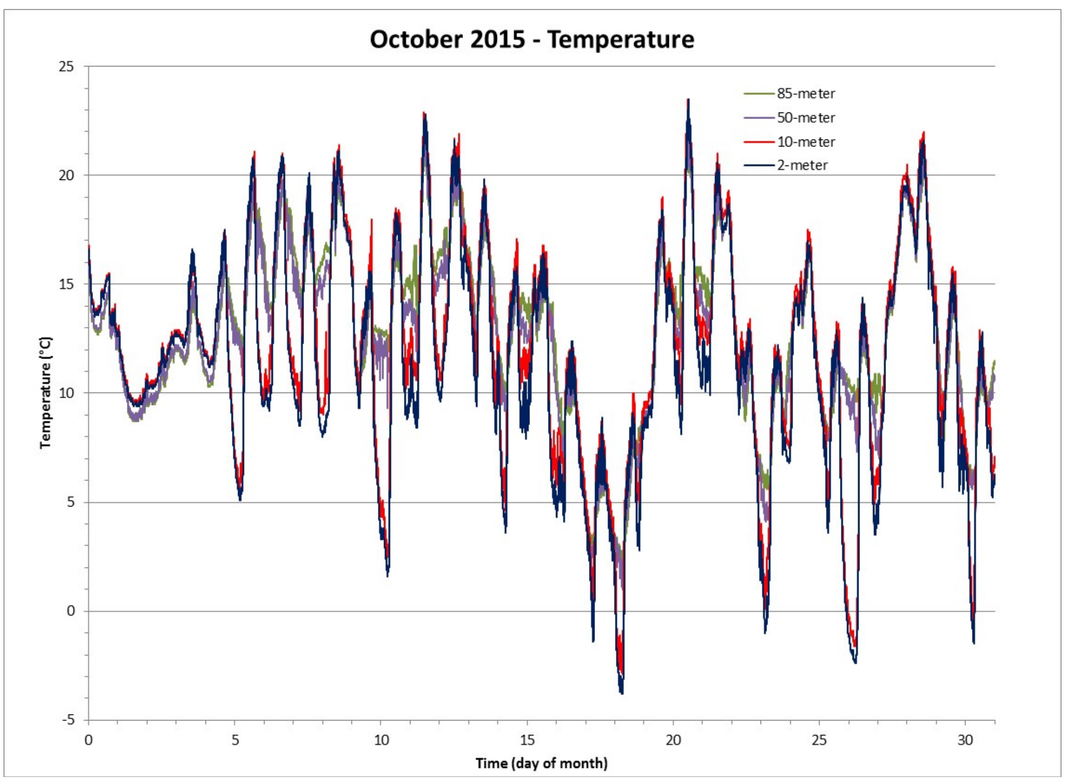

Figure 13 Air Temperature for the Month of October 2015

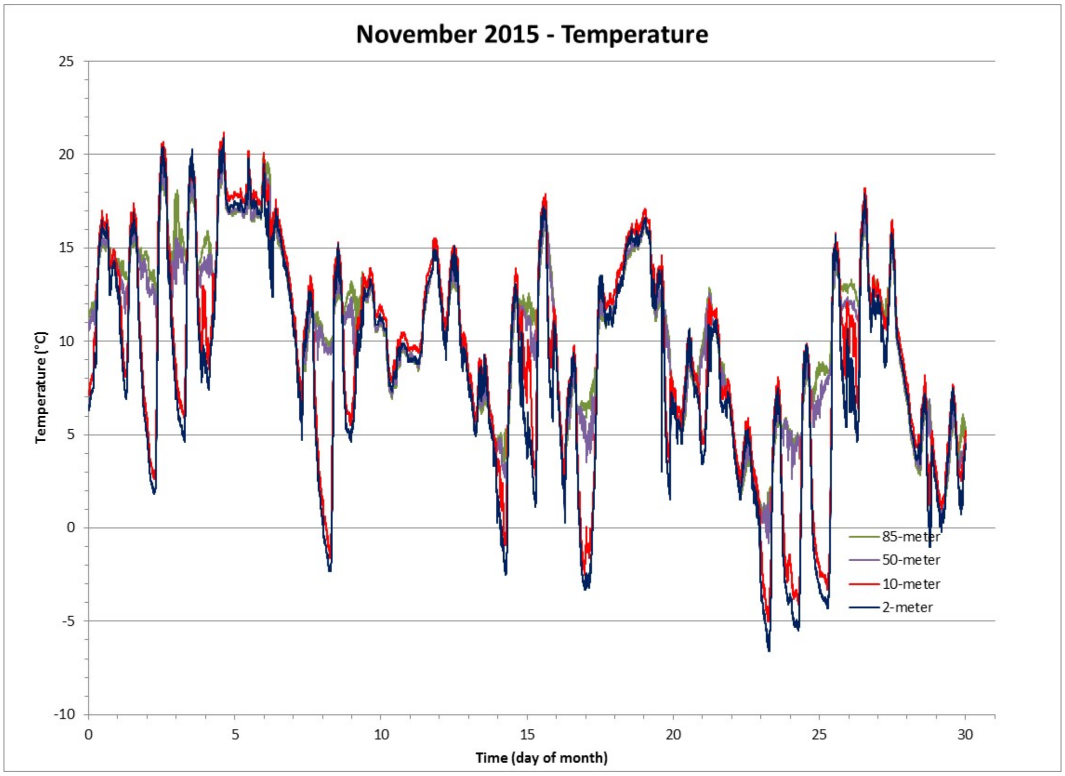

Figure 14 Air Temperature for the Month of November 2015

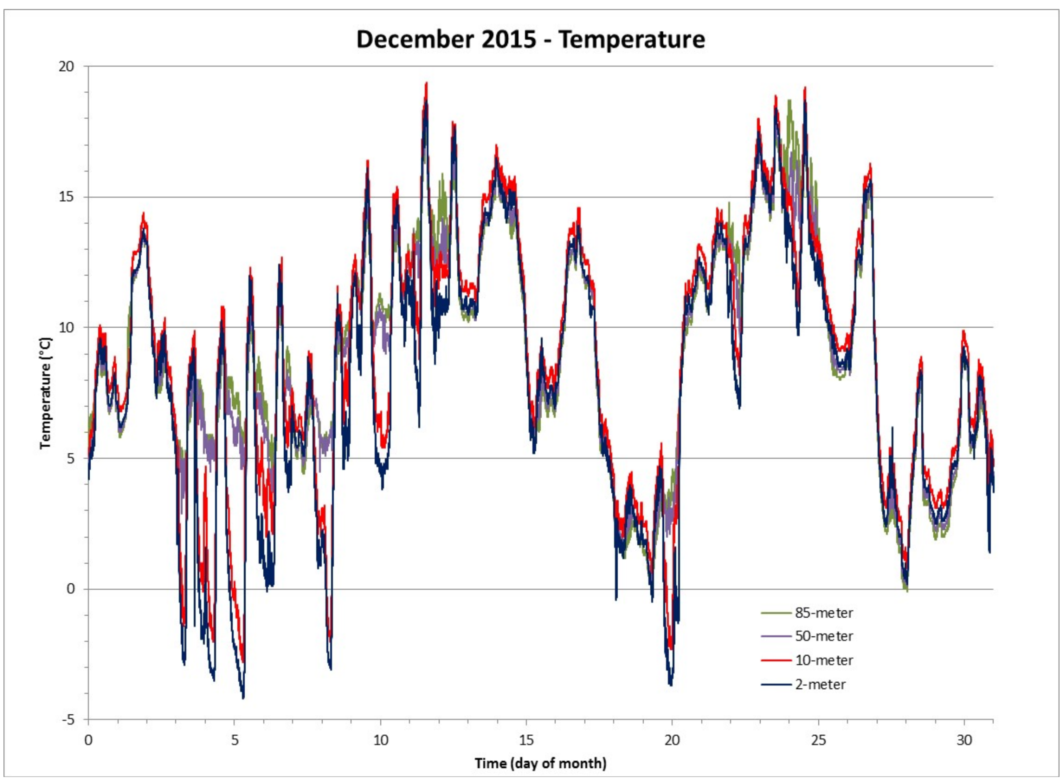

Figure 15 Air Temperature for the Month of December 2015

Table 3. Historic Monthly Mean Temperatures (°C) for Brookhaven National Laboratory from 1949 to 2015 (@ 2 meters)

Year		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1949	2.3	2.0	3.6	9.5	14.3	20.1	23.3	21.9	16.2	14.1	5.6	1.2	11.2
1950	**3.3**	-1.7	0.6	6.3	11.9	17.9	21.1	19.7	15.4	12.1	6.3	0.0	9.4
1951	0.1	-0.1	3.2	8.6	13.9	17.6	21.5	20.3	16.9	11.9	4.4	**7.2**	10.5
1952	0.2	-0.1	2.7	9.2	12.8	19.8	23.5	21.2	16.7	9.8	5.9	1.6	10.3
1953	1.2	1.6	3.8	8.4	14.6	18.3	21.5	20.2	17.4	**18.3**	6.2	3.1	11.2
1954	-3.1	1.4	2.8	8.6	11.9	18.9	20.8	19.4	16.1	13.1	4.7	0.0	9.6
1955	-2.4	-1.1	3.1	9.2	14.7	17.3	23.8	22.1	15.8	12.4	4.5	-4.1	9.6
1956	-2.2	0.3	0.7	**5.6**	11.4	18.4	20.3	20.4	15.2	15.0	5.4	2.3	9.4
1957	-4.6	0.5	3.4	9.0	13.7	20.7	21.9	19.2	17.4	10.9	7.4	2.7	10.2
1958	-1.2	-3.6	2.8	8.3	11.7	**16.3**	22.3	20.4	16.2	10.1	5.8	-4.3	8.7
1959	-2.4	-2.4	2.1	8.4	14.6	17.8	21.3	22.1	18.3	12.2	5.9	1.6	10.0
1960	-0.8	1.2	**-0.6**	8.6	14.2	18.9	20.4	20.5	15.6	10.1	6.8	-2.6	9.4
1961	-4.8	-1.4	2.5	7.1	12.3	18.9	21.6	21.3	**20.6**	12.5	6.1	0.3	9.7
1962	-1.2	-1.2	2.9	7.6	13.3	18.6	**19.3**	19.4	14.8	10.3	4.0	-2.2	8.8
1963	-2.2	-3.4	4.1	8.4	12.9	19.1	21.1	19.6	15.2	13.2	8.0	-2.9	9.4
1964	-1.0	-2.6	3.0	6.6	15.1	18.1	21.8	**18.8**	16.4	10.4	6.0	1.7	9.5
1965	-3.6	-1.6	2.1	6.6	15.3	18.2	20.3	20.3	17.1	10.5	4.8	1.2	9.3
1966	-2.3	-1.1	3.2	5.8	11.6	18.9	22.4	21.1	16.0	9.2	6.3	-0.4	9.2
1967	0.5	-4.1	0.1	6.8	**10.1**	18.5	21.6	20.6	15.4	9.9	3.5	0.4	**8.6**
1968	-4.3	-4.0	3.1	8.2	11.8	17.8	21.9	20.6	17.8	10.1	5.8	-1.2	9.0
1969	-2.3	-1.3	1.1	8.4	13.1	17.6	20.2	22.0	16.8	10.7	4.9	-0.7	9.2
1970	-5.7	-2.0	1.4	7.9	14.2	19.1	22.4	21.9	18.1	11.6	6.8	0.2	9.6
1971	-4.4	-0.7	2.8	5.9	12.2	18.6	20.7	20.3	18.9	14.4	5.0	2.8	9.7
1972	-0.4	-1.9	2.2	6.1	13.8	18.1	22.7	20.6	18.2	**8.5**	4.0	1.9	9.5

1973	-0.3	-0.8	6.1	9.6	13.0	20.8	22.4	22.2	16.7	11.3	6.6	2.2	10.8
1974	0.0	-2.5	4.1	9.7	12.9	18.4	22.2	22.1	17.1	8.8	6.3	1.6	10.1
1975	1.2	-0.8	1.7	6.6	15.4	19.2	22.9	19.1	16.1	12.3	8.5	0.8	10.2
1976	-4.6	1.6	3.6	9.8	13.1	20.1	21.1	21.2	16.4	9.7	**3.2**	-3.1	9.3
1977	**-6.9**	-1.4	5.6	8.3	14.9	18.1	22.3	22.0	18.4	10.3	6.6	0.0	9.8
1978	-3.3	-5.4	1.4	7.8	14.1	17.7	20.0	21.8	**14.5**	9.5	5.9	1.4	8.8
1979	-1.5	-6.5	5.4	7.4	15.2	17.1	22.6	21.9	16.8	11.5	8.4	3.3	10.1
1980	-1.2	-3.1	1.7	8.5	15.1	17.8	22.8	21.6	18.7	11.5	4.7	-1.7	9.7
1981	-6.9	0.3	2.6	9.3	14.6	20.2	23.6	21.6	17.1	9.7	6.5	0.5	9.9
1982	-5.2	-0.5	2.2	7.2	14.8	17.2	22.2	20.1	16.5	11.1	7.6	4.0	9.8
1983	0.0	-0.9	5.0	8.7	12.4	19.3	23.0	21.9	18.6	11.8	7.2	-0.3	10.6
1984	-4.0	2.8	0.7	8.4	12.8	20.1	21.4	22.1	15.6	13.0	6.1	3.9	10.2
1985	-4.2	-0.4	4.7	10.0	14.8	17.3	21.9	20.7	17.9	11.7	8.2	-0.9	10.1
1986	-1.1	-2.1	3.8	8.6	15.1	18.4	21.8	19.9	16.2	11.6	5.2	1.9	9.9
1987	-1.5	-1.5	4.4	9.7	14.4	20.2	22.9	20.2	17.2	9.6	6.7	1.5	10.3
1988	-4.2	-0.7	3.2	7.8	14.3	18.8	23.3	23.0	16.1	8.9	6.5	-0.2	9.7
1989	0.4	-1.1	3.2	7.7	14.3	20.3	21.9	21.8	17.7	11.9	5.6	**-4.5**	9.9
1990	2.9	1.8	4.4	8.7	13.2	19.3	22.5	22.3	17.0	14.2	7.6	4.1	11.5
1991	-0.6	1.9	5.4	10.6	**16.9**	20.3	22.7	22.7	16.8	12.6	7.1	2.6	11.6
1992	-0.5	0.4	2.3	7.2	13.2	18.2	20.6	20.1	17.3	10.2	5.9	1.6	9.7
1993	0.7	-2.9	1.9	9.1	15.3	19.8	23.3	22.1	17.7	10.4	5.8	1.2	10.4
1994	-4.1	-2.5	3.1	9.9	13.5	21.1	**24.9**	20.6	17.2	11.4	9.1	3.7	10.7
1995	2.6	-1.3	4.9	8.1	13.4	19.4	23.6	22.2	17.0	13.6	5.1	-1.1	10.6
1996	-1.6	-0.4	1.4	8.6	13.7	19.6	21.1	21.4	18.0	11.2	4.3	3.6	10.1
1997	-1.1	2.5	3.2	8.3	12.6	18.6	22.3	21.2	17.1	11.1	5.2	1.9	10.2
1998	3.3	2.9	4.8	9.2	15.6	18.7	22.4	22.4	18.7	12.2	6.7	3.4	11.7
1999	0.1	1.3	4.1	9.1	14.8	20.7	24.6	22.1	18.7	11.1	8.6	3.1	11.5

2000	-1.8	1.1	6.1	8.2	15.1	19.6	20.6	21.4	17.3	11.8	6.0	-1.6	10.3
2001	-1.4	0.2	2.6	9.6	15.2	21.1	20.7	23.5	17.6	12.3	9.0	4.7	11.3
2002	3.0	2.3	5.4	**10.8**	13.8	19.3	23.4	23.3	18.7	11.5	6.2	0.6	11.5
2003	-3.2	-2.2	3.6	8.0	12.9	18.8	22.7	23.7	18.8	11.2	8.5	2.3	10.4
2004	-4.7	0.3	4.4	9.7	16.2	19.4	22.1	21.6	19.0	11.9	7.1	1.6	10.7
2005	-1.8	0.1	1.7	9.5	12.3	20.8	23.4	**24.6**	20.2	13.2	8.3	0.7	11.1
2006	3.0	0.2	3.8	9.9	14.9	20.2	23.8	22.4	17.1	11.7	9.2	4.9	11.8
2007	2.1	-2.2	3.4	7.9	15.3	19.6	22.4	22.2	18.7	16.1	5.8	1.3	11.1
2008	1.0	1.3	2.7	10.1	13.3	21.3	23.6	21.6	17.7	11.1	5.8	3.7	11.1
2009	-3.3	1.1	3.4	10.1	14.6	17.8	21.1	22.8	16.9	11.4	9.3	1.3	10.6
2010	-1.3	-0.3	6.8	10.7	16.2	**21.3**	24.6	22.7	19.7	12.8	7.1	-0.4	11.7
2011	-2.7	0.3	4.0	9.9	15.8	20.2	24.1	22.3	19.6	12.7	**9.4**	4.7	11.7
2012	2.2	**3.2**	**8.0**	10.7	16.4	19.6	23.3	22.7	18.3	14.0	5.2	4.4	**12.3**
2013	0.9	0.2	3.2	9.2	14.4	20.1	24.4	21.1	17.1	13.3	5.9	2.1	11.0
2014	-2.7	-1.8	1.3	8.3	14.8	19.3	22.0	20.3	18.0	13.3	5.6	3.3	10.1
2015	-2.6	**-6.9**	0.7	8.7	16.0	19.1	23.1	23.1	20.2	11.4	8.6	8.1	10.8
Average	**-1.4**	-0.7	3.2	8.5	14.0	19.1	**22.2**	21.4	17.3	11.7	6.4	1.3	10.2
Max	3.3	3.2	8.0	10.8	16.9	21.3	**24.9**	24.6	20.6	18.3	9.4	8.1	12.3
Min	**-6.9**	**-6.9**	-0.6	5.6	10.1	16.3	19.3	18.8	14.5	8.5	3.2	-4.5	8.6

Min **Max**

Table 4. Historic Monthly Mean Maximum Temperatures (°F) for Brookhaven National Laboratory from 1949 to 2015 (@ 2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1949	6.6	7.1	8.4	15.0	20.4	26.0	28.7	27.9	21.7	19.9	11.5	6.9	16.7
1950	**8.3**	3.1	6.3	12.0	17.9	24.4	27.1	25.3	21.1	18.9	12.8	5.3	15.2
1951	5.8	6.1	8.3	15.8	21.4	23.6	27.5	26.2	23.8	17.7	10.4	7.3	16.2
1952	5.4	4.9	7.1	15.4	19.5	26.3	30.5	27.2	**29.1**	16.8	12.0	6.3	16.7
1953	6.2	7.0	8.7	**24.1**	20.2	26.1	28.6	27.0	24.7	18.8	13.4	8.6	**17.8**
1954	2.6	7.7	8.9	15.2	18.4	25.2	27.8	25.8	22.1	19.5	10.5	4.5	15.7
1955	1.7	4.2	8.2	14.9	22.4	23.9	29.6	27.9	22.1	18.4	9.8	1.0	15.3
1956	1.9	4.9	5.8	12.2	18.1	25.7	25.4	26.5	21.1	17.7	11.3	7.6	14.9
1957	0.4	5.6	9.2	15.5	20.6	**27.2**	28.6	25.8	23.4	16.9	13.0	7.9	16.2
1958	3.1	0.7	7.1	14.5	17.3	22.3	27.3	25.9	22.1	15.8	11.6	1.3	**14.1**
1959	2.8	3.1	7.1	14.5	21.3	23.5	26.2	27.4	24.6	17.7	11.2	6.6	15.5
1960	3.4	6.1	**4.1**	15.2	20.7	25.2	26.6	26.1	21.3	17.4	13.2	3.7	15.3
1961	1.1	4.7	7.7	12.4	18.3	25.1	27.1	26.7	25.9	18.7	11.3	4.7	15.3
1962	3.8	2.8	8.8	14.1	20.6	24.7	25.9	25.3	21.1	16.9	9.6	3.3	14.7
1963	3.2	2.2	9.0	15.5	20.1	25.8	27.4	25.6	**20.6**	20.6	12.9	1.6	15.3
1964	4.4	2.6	8.2	12.2	22.7	24.3	26.2	25.5	22.8	17.3	13.2	6.0	15.4
1965	1.5	3.2	6.9	12.8	22.6	24.8	26.6	26.0	22.4	16.3	10.6	6.5	15.0
1966	2.2	4.1	8.6	12.1	17.7	25.3	29.3	27.6	21.9	17.1	12.6	4.9	15.3
1967	5.7	2.1	5.7	12.8	**16.3**	24.8	26.6	**25.2**	22.2	17.0	8.9	6.2	14.4
1968	0.7	1.9	9.2	16.6	18.8	23.2	28.0	26.8	25.0	18.6	10.4	3.6	15.2
1969	2.1	2.2	6.3	14.6	19.9	23.8	**24.9**	27.6	22.9	17.5	10.3	3.6	14.7
1970	-0.7	3.9	6.3	14.1	19.9	24.4	27.4	28.1	24.1	18.1	11.9	4.5	15.2
1971	0.4	4.1	7.4	12.6	18.3	25.4	26.7	26.9	23.8	20.6	10.0	7.8	15.3
1972	5.3	3.6	7.2	12.4	20.4	22.9	27.8	26.9	24.3	15.2	**8.2**	5.4	14.9
1973	5.0	3.6	11.1	15.1	18.1	25.9	28.1	28.9	23.6	18.6	11.6	7.7	16.4

1974	5.0	2.8	9.4	15.7	18.9	23.9	28.4	28.5	22.4	15.7	12.3	6.7	15.8
1975	5.9	4.2	7.4	12.7	21.9	24.4	28.1	27.3	21.6	18.4	14.3	5.8	16.0
1976	1.1	8.2	9.1	17.1	19.2	25.9	26.7	26.9	22.9	**14.7**	8.6	2.5	15.3
1977	**-1.9**	3.5	11.1	14.8	22.3	23.8	28.6	27.6	23.2	15.9	11.2	4.5	15.4
1978	1.5	0.2	6.9	13.6	19.1	24.4	25.6	26.6	21.2	16.1	11.2	6.6	14.4
1979	2.8	**-2.6**	10.6	13.2	20.2	22.8	28.2	26.4	22.8	16.5	13.4	7.4	15.2
1980	3.5	1.6	6.3	14.0	21.7	24.1	27.6	28.6	24.9	16.7	9.6	3.7	15.2
1981	-1.5	5.6	8.1	14.7	20.8	25.7	29.2	26.9	22.0	15.1	11.1	4.6	15.2
1982	-0.1	3.6	7.7	13.8	20.8	**22.0**	28.2	25.8	22.7	18.2	13.1	9.0	15.4
1983	4.8	5.7	9.7	14.3	18.0	26.7	29.6	27.8	25.6	17.4	12.7	4.8	16.4
1984	1.2	7.5	5.7	13.9	18.8	26.2	26.4	27.8	22.4	18.7	11.8	9.8	15.8
1985	0.9	4.6	10.9	16.2	21.4	23.5	28.0	26.6	24.6	18.6	12.8	4.0	16.0
1986	4.6	2.3	10.3	15.0	22.3	24.6	27.2	25.4	21.7	17.7	10.8	6.3	15.7
1987	3.3	3.6	10.7	15.4	21.0	26.1	28.6	26.2	22.8	17.1	12.7	6.5	16.2
1988	1.6	4.5	9.3	13.1	20.2	25.7	28.6	28.6	22.8	15.0	12.9	5.4	15.7
1989	6.0	3.7	8.2	14.1	20.1	25.7	27.2	27.1	23.8	18.6	10.8	**0.4**	15.5
1990	7.3	7.4	10.4	13.9	18.9	25.1	27.2	27.1	23.1	19.9	13.8	9.1	16.9
1991	4.9	7.5	10.3	16.4	**23.7**	26.7	28.8	28.2	22.7	18.4	11.9	7.9	17.3
1992	5.0	5.7	7.7	12.9	20.1	23.9	26.2	25.5	22.3	16.4	10.8	6.4	15.2
1993	5.2	3.1	6.8	14.4	22.2	25.7	29.6	27.9	22.6	16.2	12.5	6.1	16.0
1994	1.1	2.6	8.3	16.5	20.1	26.7	29.9	26.2	23.0	18.1	14.4	9.1	16.3
1995	6.6	4.2	10.4	14.3	19.3	25.1	28.5	29.1	23.4	20.2	10.1	4.2	16.3
1996	3.1	4.4	7.3	14.1	19.8	24.6	25.3	26.3	22.8	17.4	9.5	7.8	15.2
1997	3.8	7.4	8.7	14.4	18.7	25.3	28.4	26.9	23.2	17.8	10.0	6.9	15.9
1998	7.7	7.8	9.7	15.2	21.7	23.7	28.1	28.3	24.7	17.8	12.3	9.2	17.2
1999	5.6	6.6	9.7	15.9	21.7	26.8	**30.7**	27.1	23.9	17.7	14.1	8.1	17.3
2000	3.2	6.2	12.2	**13.5**	21.1	25.0	25.8	26.3	23.1	18.0	11.1	3.2	15.7
2001	3.9	5.6	7.2	15.8	21.3	26.8	26.6	27.5	23.9	18.9	**15.2**	10.0	16.9
2002	7.7	**8.7**	10.8	16.9	19.9	25.3	29.4	28.9	24.4	16.6	10.9	5.6	17.1

2003	0.8	2.3	10.2	13.3	18.4	23.8	27.7	28.1	23.7	16.8	13.7	7.2	15.5
2004	-0.7	5.6	8.8	14.9	21.8	25.1	27.0	26.4	24.7	16.9	12.6	7.0	15.8
2005	2.7	5.6	7.3	16.5	18.0	25.9	28.5	**30.0**	27.3	17.6	13.7	5.4	16.6
2006	7.8	5.7	9.3	16.8	20.3	24.7	28.7	27.7	22.5	17.4	14.1	**10.1**	17.1
2007	6.1	2.0	9.2	13.7	22.3	25.3	27.6	27.4	24.9	**21.1**	11.1	5.7	16.4
2008	5.4	6.3	8.4	16.4	19.4	27.0	28.9	27.6	22.7	17.0	10.4	8.3	16.5
2009	1.0	6.1	8.9	15.8	19.8	22.9	26.3	28.1	22.4	16.6	13.2	5.3	15.6
2010	2.6	3.2	12.1	18.3	22.4	26.7	30.4	27.8	24.6	17.8	11.7	2.9	16.7
2011	0.9	5.4	8.9	14.9	21.3	25.7	29.6	27.3	24.3	17.8	14.8	9.7	16.7
2012	7.0	7.9	**13.2**	16.8	21.3	25.0	28.7	28.0	23.4	18.2	10.1	8.5	17.3
2013	4.9	3.7	7.4	15.1	20.6	25.3	29.0	26.6	23.3	19.3	11.4	6.7	16.1
2014	2.6	3.9	7.6	14.8	20.8	25.3	27.1	26.4	23.3	17.7	10.4	6.9	15.6
2015	1.4	-1.6	5.8	14.4	22.1	24.2	28.1	29.0	26.8	16.9	14.0	12.5	16.1
Average	**3.4**	4.4	8.5	14.8	20.2	25.0	**27.8**	27.1	23.3	17.7	11.8	6.1	15.8
Max	8.3	8.7	13.2	24.1	23.7	27.2	**30.7**	30.0	29.1	21.1	15.2	12.5	17.8
Min	-1.9	**-2.6**	4.1	12.0	16.3	22.0	24.9	25.2	20.6	14.7	8.2	0.4	14.1

Min **Max**

Table 5. Historic Monthly Mean Minimum Temperatures (°F) for Brookhaven National Laboratory from 1949 to 2015 (@2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1949	-1.7	-3.1	-0.8	4.3	7.9	14.1	17.9	15.8	10.7	8.3	-0.4	-4.4	5.7
1950	-1.7	-6.6	-5.1	0.7	5.9	11.4	15.2	13.9	10.0	5.0	0.0	-4.2	3.7
1951	-5.6	-5.0	-2.5	1.4	6.7	12.2	15.8	14.4	9.9	5.9	-1.3	-4.2	4.0
1952	-5.0	-5.1	-2.1	3.4	6.8	13.2	16.4	15.4	9.2	2.7	0.1	-3.2	4.3
1953	-3.3	-3.8	-1.1	2.9	9.1	11.6	14.3	13.0	10.1	4.1	-1.2	-2.6	4.4
1954	-8.1	-4.1	-3.1	1.9	5.0	12.6	13.9	13.2	10.4	6.3	-1.4	-4.6	3.5
1955	-6.7	-6.4	-2.5	3.5	7.0	10.7	18.1	16.2	9.8	6.4	-0.6	-9.2	3.9
1956	-6.3	-4.2	-4.6	**-1.1**	4.8	10.9	15.1	14.3	9.2	3.1	-0.3	-2.9	3.2
1957	-9.7	-4.7	-2.2	2.6	6.8	14.3	15.3	12.6	11.4	4.8	1.8	-2.3	4.2
1958	-5.5	-7.8	-1.2	2.1	6.1	**10.3**	17.3	14.7	10.4	4.3	0.1	**-9.9**	3.4
1959	-7.6	-7.7	-2.9	2.3	7.8	12.2	16.5	16.8	12.1	6.7	0.6	-3.6	4.4
1960	-5.1	-3.1	-5.1	2.0	7.5	12.6	14.4	15.0	9.9	2.8	0.4	-8.7	3.6
1961	-10.7	-7.0	-2.7	1.8	6.7	12.4	16.1	15.8	15.2	6.4	0.8	-4.7	4.2
1962	-7.5	-6.7	-2.6	1.2	6.1	12.3	**12.3**	13.4	8.6	3.9	-1.5	-7.6	**2.7**
1963	-7.7	-9.0	-1.1	1.4	5.9	12.4	15.2	13.6	9.9	5.9	3.2	-6.8	3.6
1964	-6.4	-7.9	-2.2	0.9	7.6	12.1	17.4	**12.2**	10.1	3.6	-1.1	-2.6	3.7
1965	-8.9	-6.1	-2.8	0.3	8.1	11.6	13.9	14.5	11.8	4.4	-0.9	-4.0	3.5
1966	-6.8	-6.4	-2.4	-0.4	5.5	12.6	15.6	14.6	10.2	**1.4**	0.4	-5.7	3.2
1967	-4.5	-10.0	**-5.5**	0.8	4.1	12.3	17.4	16.2	8.9	3.1	-1.8	-5.4	2.9
1968	-9.1	-9.8	-2.8	-0.1	5.3	12.6	15.8	14.4	10.6	6.9	1.1	-6.1	3.3
1969	-6.7	-4.9	-4.1	2.2	6.2	11.4	15.6	16.1	10.7	4.5	-0.4	-4.9	3.8
1970	-10.7	-7.9	-3.6	1.9	8.4	13.6	17.3	15.6	12.1	5.4	1.7	-4.1	4.1
1971	-9.5	-5.4	-1.9	-0.7	6.1	12.2	14.8	13.6	14.2	8.6	0.0	-2.1	4.2

1972	-6.2	-7.5	-2.6	-0.3	6.9	13.2	17.7	13.9	12.0	1.8	-0.2	-1.6	3.9
1973	-6.0	-5.2	0.9	4.1	7.9	15.8	16.7	17.5	10.0	3.9	1.6	-2.2	5.4
1974	-5.0	-7.9	-1.3	3.7	6.9	13.2	16.0	15.4	11.9	2.1	0.2	-3.5	4.3
1975	-3.4	-5.9	-4.0	0.5	9.1	13.9	17.8	16.1	10.5	6.3	3.2	-4.8	4.9
1976	-10.4	-5.3	-1.8	2.6	6.9	14.2	15.4	15.4	9.8	4.7	**-2.3**	-8.6	3.4
1977	-12.2	-6.5	0.0	0.9	7.4	12.3	16.1	16.5	13.6	4.7	1.9	-4.5	4.2
1978	-8.1	**-11.5**	-3.9	1.9	8.9	11.0	14.4	17.0	**7.7**	2.9	0.5	-3.9	3.1
1979	-5.8	-10.5	-0.3	1.6	10.2	11.4	16.9	17.4	10.8	6.4	3.3	-1.0	5.1
1980	-5.8	-7.7	-2.9	2.9	8.6	11.6	18.0	17.9	12.3	6.3	-0.3	-6.9	4.5
1981	**-12.3**	-4.9	-3.4	4.0	8.3	14.7	18.0	15.9	12.2	4.3	2.0	-3.6	4.6
1982	-10.4	-4.6	-3.4	0.7	8.7	12.3	16.3	14.4	10.3	4.1	2.1	-1.0	4.1
1983	-4.8	-5.5	0.3	3.1	6.8	11.9	16.4	16.1	11.7	6.1	1.7	-5.3	4.9
1984	-9.3	**-1.8**	-4.2	2.9	6.9	13.9	16.3	16.4	8.8	7.3	0.2	-1.9	4.6
1985	-9.3	-5.4	-1.4	3.8	8.2	11.1	15.8	14.8	11.2	4.8	3.6	-5.8	4.3
1986	-6.7	-6.6	-2.7	2.1	7.8	12.2	16.4	14.5	10.8	5.4	-0.6	-2.5	4.2
1987	-6.3	-6.6	-1.9	3.9	7.8	14.4	17.2	14.1	11.5	2.2	0.7	-3.6	4.4
1988	-10.0	-5.9	-3.1	2.5	8.3	12.0	17.9	17.4	9.4	2.8	0.1	-5.8	3.8
1989	-5.2	-5.9	-2.4	1.3	8.6	14.9	16.6	16.7	11.6	5.3	0.3	-9.4	4.3
1990	-1.4	-3.8	-1.6	3.5	7.4	13.6	17.8	17.4	10.9	8.3	1.4	-0.9	6.1
1991	-6.0	-3.6	0.6	4.7	10.1	13.9	16.7	17.2	10.8	6.8	2.2	-2.6	5.9
1992	-5.9	-4.7	-3.1	1.7	6.2	12.5	15.1	14.7	12.4	3.9	1.1	-3.3	4.2
1993	-3.8	-8.9	-2.9	3.6	8.5	13.8	16.9	16.2	12.8	4.7	-1.1	-3.7	4.7
1994	-9.1	-7.7	-2.2	3.4	6.9	15.4	20.0	14.9	11.4	4.7	3.7	-1.7	5.0
1995	-1.6	-6.9	-0.6	1.8	7.5	13.8	18.7	15.3	10.7	6.9	0.2	-5.9	5.0
1996	-6.2	-5.3	-4.6	3.2	7.6	14.7	16.8	16.6	13.2	4.9	-0.9	-0.7	4.9
1997	-5.8	-2.4	-2.3	2.2	6.6	11.9	16.1	15.6	11.1	4.4	0.3	-3.1	4.6
1998	**-1.2**	-1.9	-0.1	3.1	9.6	13.8	16.7	16.4	12.7	6.6	1.2	-2.3	6.2
1999	-5.3	-4.0	-1.6	2.3	8.0	14.6	18.4	16.9	13.5	4.4	3.1	-1.9	5.7
2000	-6.9	-4.1	-0.1	2.9	9.1	14.2	15.3	16.4	11.5	5.7	0.9	-6.2	4.9

2001	-6.8	-5.1	-2.1	3.3	9.2	15.4	14.7	18.1	11.3	5.8	2.9	-0.6	5.5
2002	-1.7	-4.1	0.0	4.7	7.8	13.3	17.5	17.6	12.9	6.3	1.5	-4.4	5.9
2003	-7.2	-6.7	-2.9	2.7	6.8	13.8	17.7	**19.2**	13.9	5.6	3.3	-2.4	5.3
2004	-8.7	-5.0	0.2	4.6	10.6	13.8	17.2	16.8	13.3	6.8	1.6	-3.8	5.6
2005	-6.3	-5.6	1.7	2.5	6.6	15.6	18.2	19.1	13.1	8.8	2.9	-4.1	6.1
2006	-1.8	-5.3	-1.7	3.1	9.6	15.6	18.9	17.0	11.7	5.9	4.4	-0.1	6.4
2007	-2.7	-7.1	-2.6	2.2	8.4	13.9	17.3	16.9	12.6	**11.2**	0.5	-3.0	5.6
2008	-4.0	-4.1	-3.1	4.1	7.4	15.8	18.5	16.0	12.7	5.1	0.8	-1.7	5.6
2009	-7.9	-3.9	-1.9	4.2	9.6	13.8	15.8	18.1	11.2	6.0	**4.8**	-3.1	5.6
2010	-5.8	-4.2	1.5	**5.5**	10.0	**15.9**	19.1	17.3	14.6	7.3	1.9	-4.2	6.6
2011	-7.3	-5.4	-0.8	5.2	10.9	14.9	18.6	17.4	**15.8**	7.8	4.0	-1.5	6.7
2012	-3.2	-2.6	**3.0**	3.8	**11.9**	13.9	18.5	17.4	12.7	9.4	0.0	**-0.1**	**7.1**
2013	-4.5	-3.9	-1.4	3.4	8.3	15.0	**20.3**	15.3	10.8	7.0	0.1	-2.6	5.7
2014	-8.7	-7.7	-5.1	1.7	8.7	13.4	**17.3**	14.5	12.3	8.3	0.5	-0.5	4.6
2015	-7.5	**-13.6**	-4.4	2.1	10.0	14.1	18.1	17.0	14.3	5.5	2.7	3.7	5.2
Average	**-6.4**	-5.9	-2.1	2.4	7.7	13.2	**16.7**	15.8	11.4	5.4	0.9	-3.7	4.6
Max	-1.2	-1.8	3.0	5.5	11.9	15.9	**20.3**	19.2	15.8	11.2	4.8	3.7	7.1
Min	-12.3	**-13.6**	-5.5	-1.1	4.1	10.3	12.3	12.2	7.7	1.4	-2.3	-9.9	2.7

Min **Max**

Barometric Pressure

Barometric pressure is measured at the 2-meter level. The pressure sensors are connected to R.M. Young model 61002 pressure ports to reduce errors due to blowing winds. The sensors are sent off-site for calibration. Average daily pressure for 2015 is plotted in Figure 16. The lowest pressure, 982.5 mbar, occurred on January 31st. Monthly data plots of the 1-minute data for pressure are presented in Figures 17 through 28.

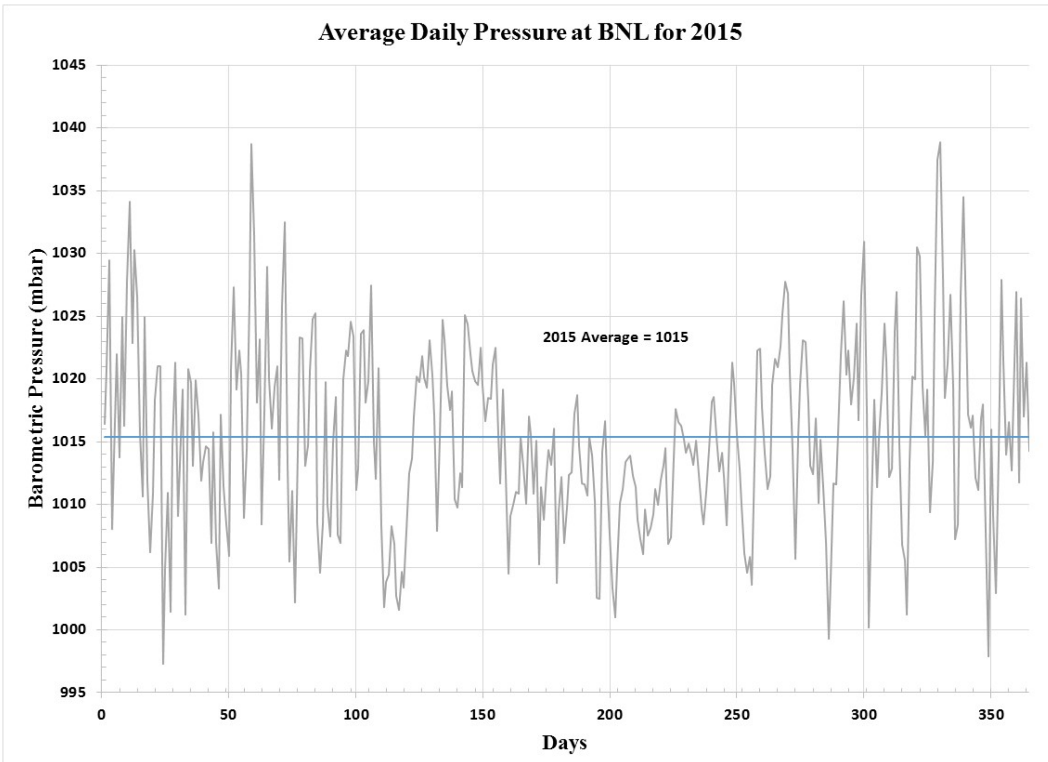

Figure 16 Average Daily Barometric Pressure at Brookhaven National Laboratory for 2015

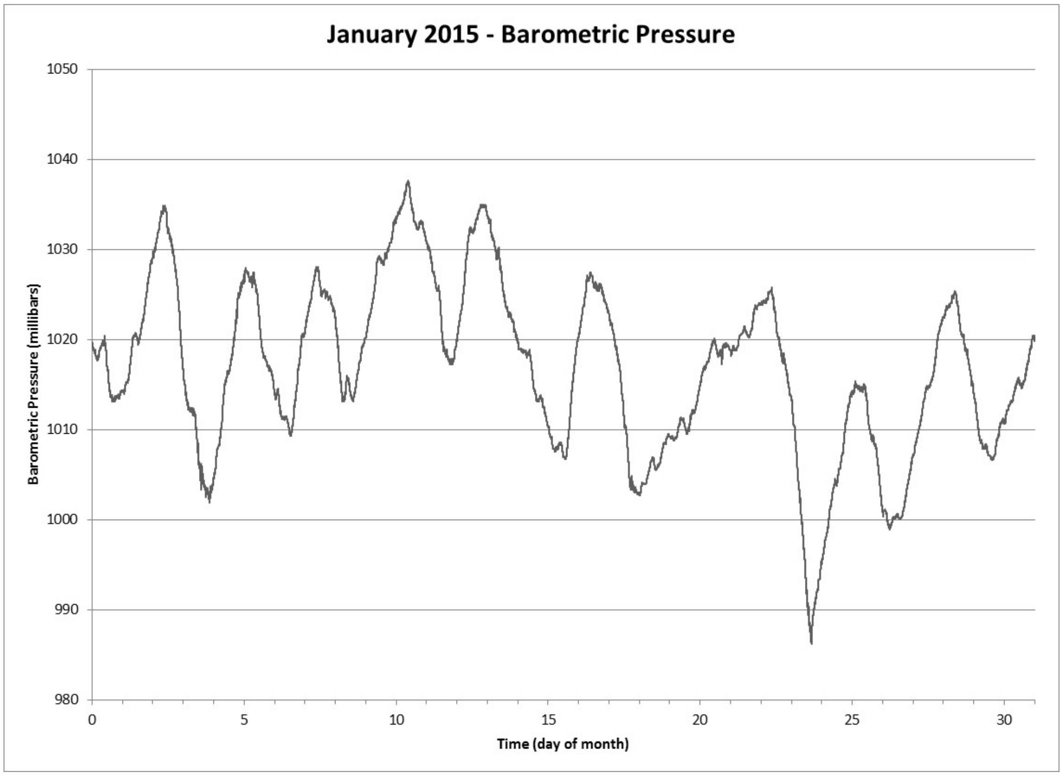

Figure 17 Barometric Pressure for the Month of January 2015

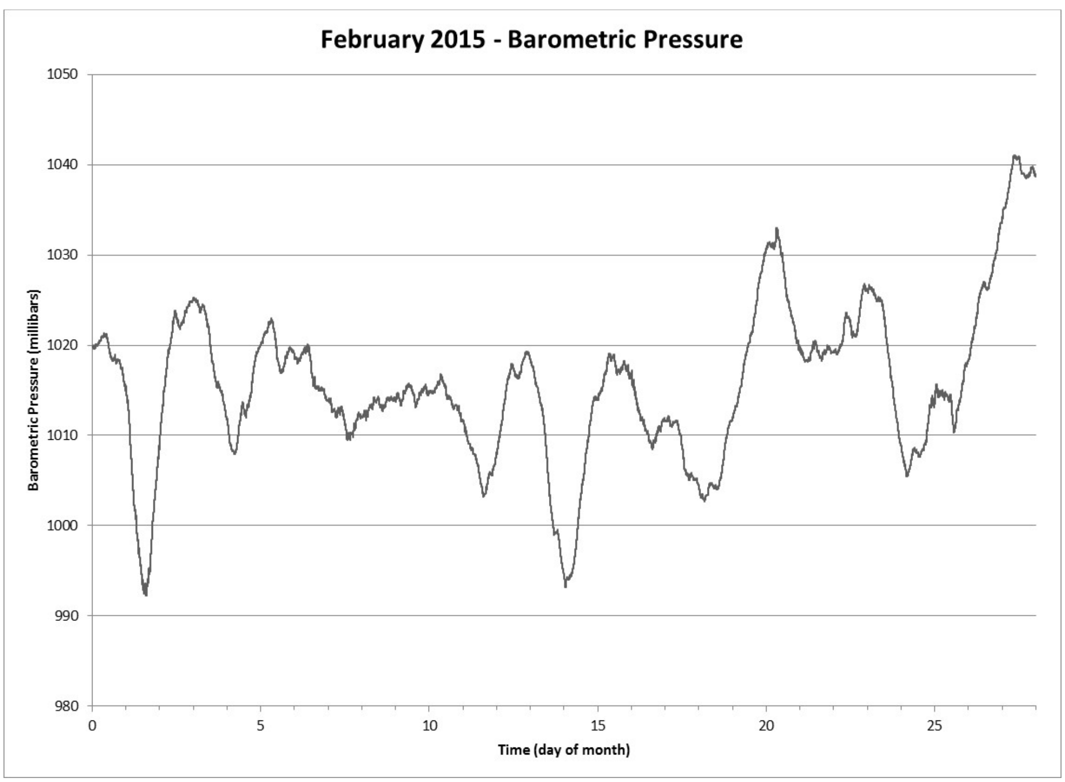

Figure 18 Barometric Pressure for the Month of February 2015

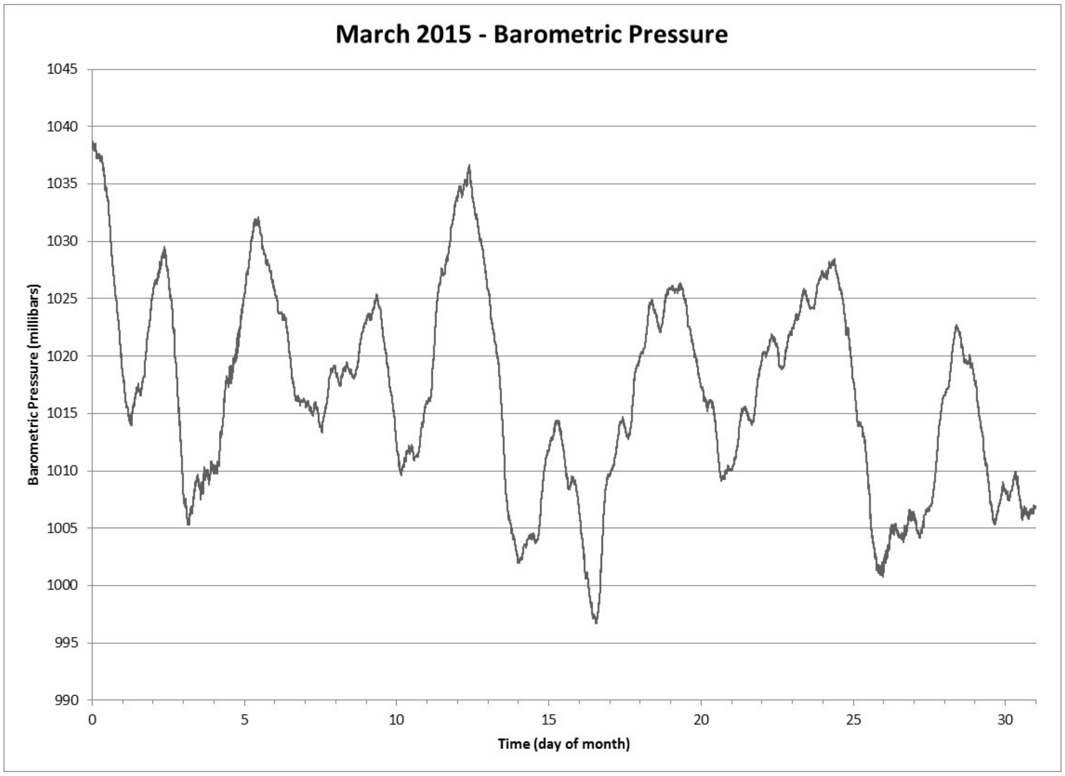

Figure 19 Barometric Pressure for the Month of March 2015

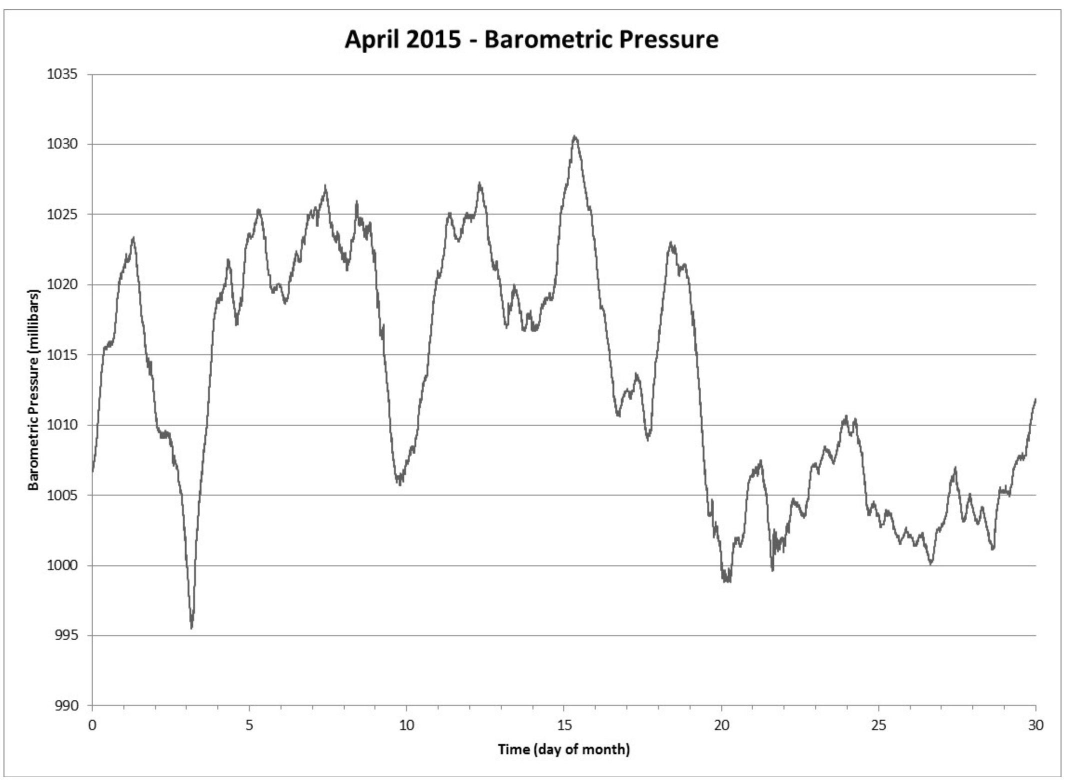

Figure 20 Barometric Pressure for the Month of April 2015

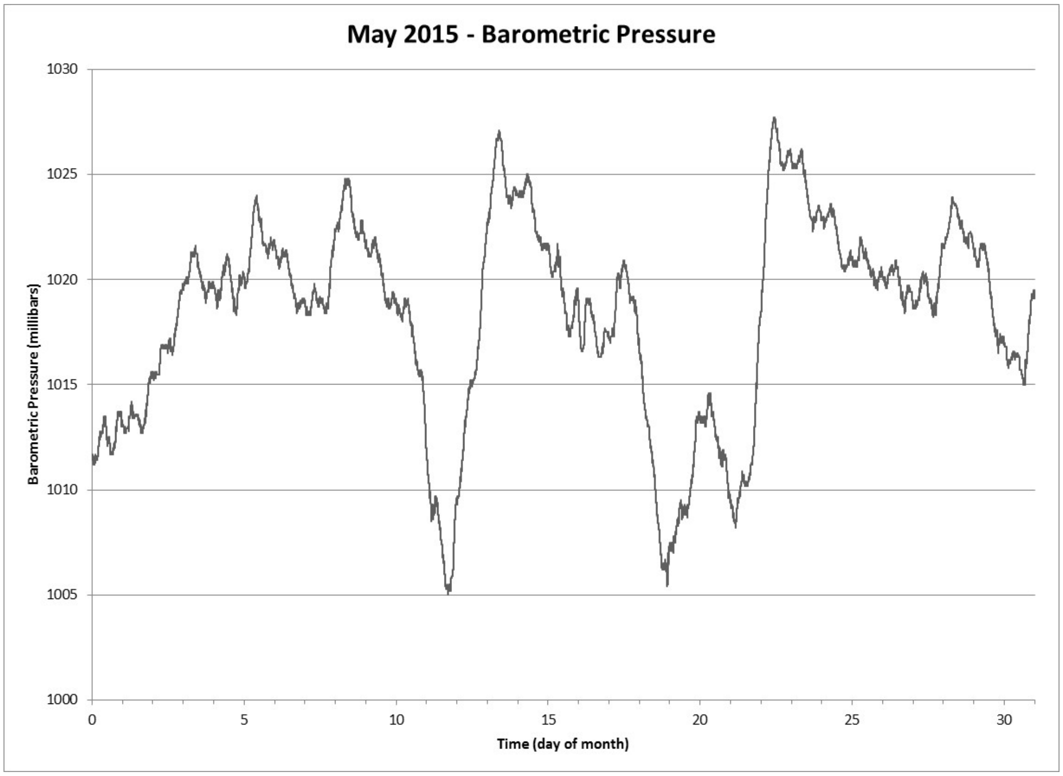

Figure 21 Barometric Pressure for the Month of May 2015

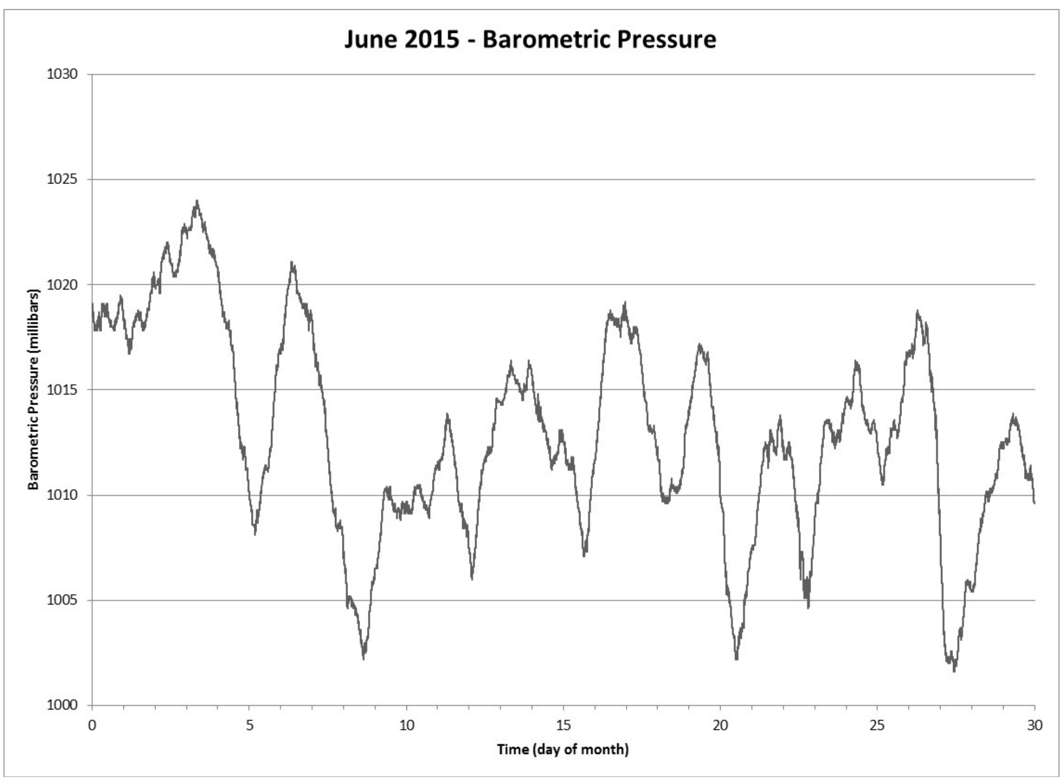

Figure 22 Barometric Pressure for the Month of June 2015

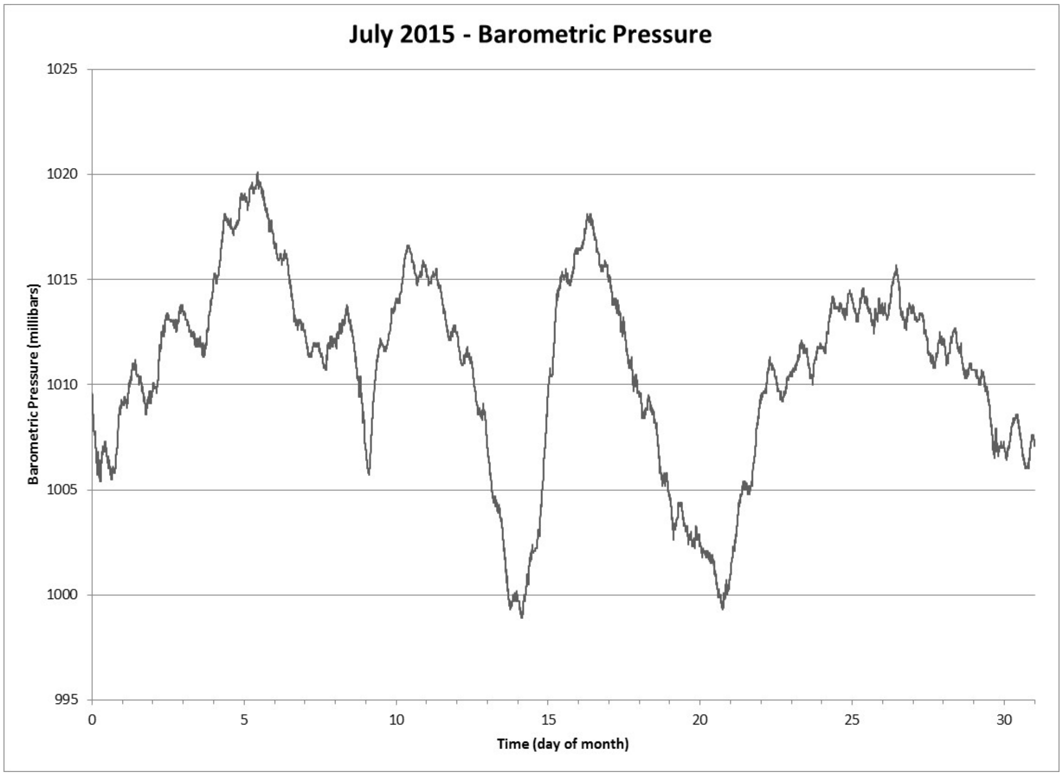

Figure 23 Barometric Pressure for the Month of July 2015

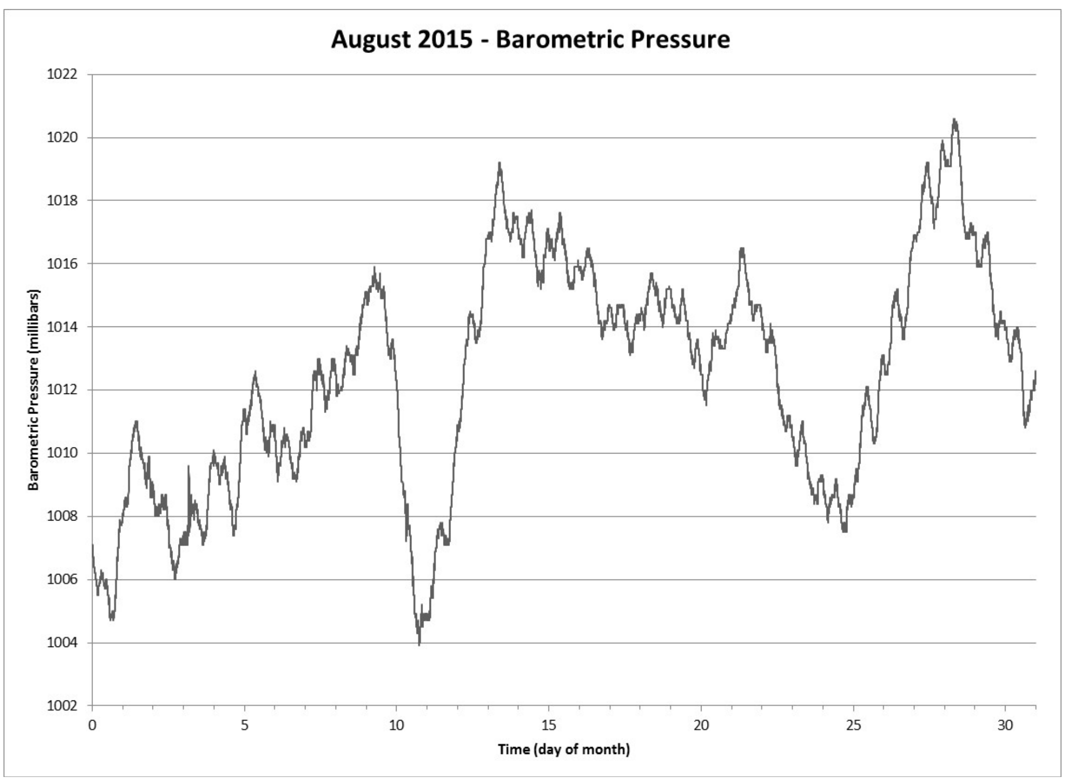

Figure 24 Barometric Pressure for the Month of August 2015

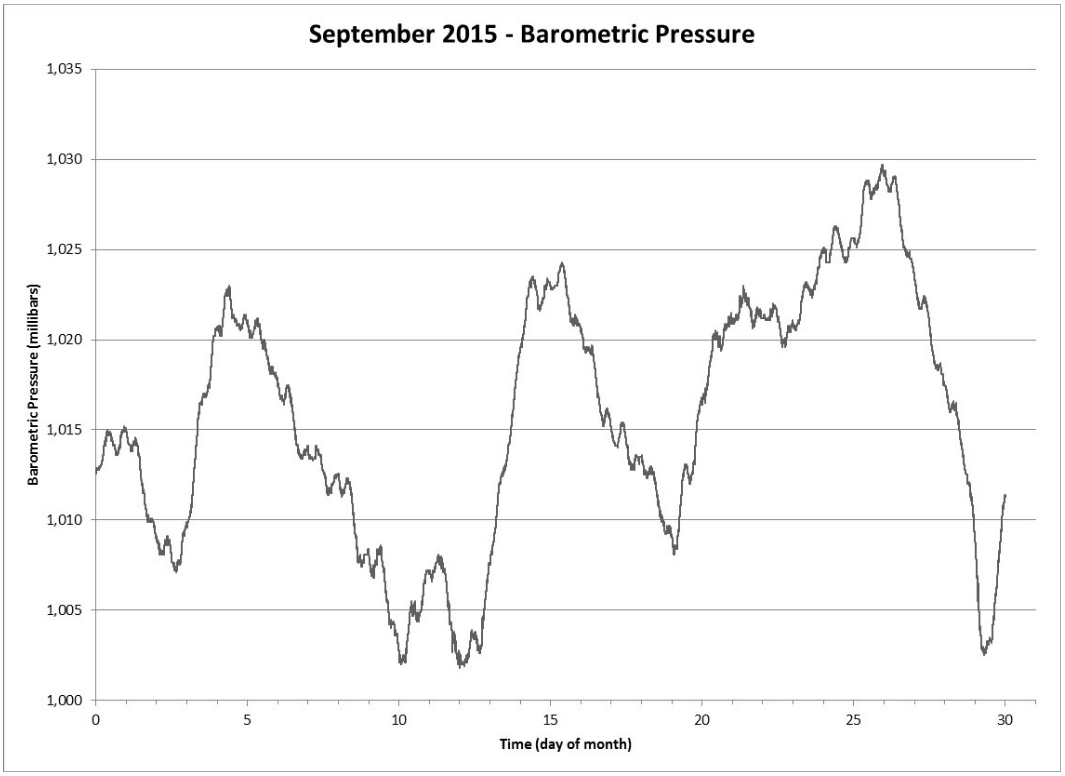

Figure 25 Barometric Pressure for the Month of September 2015

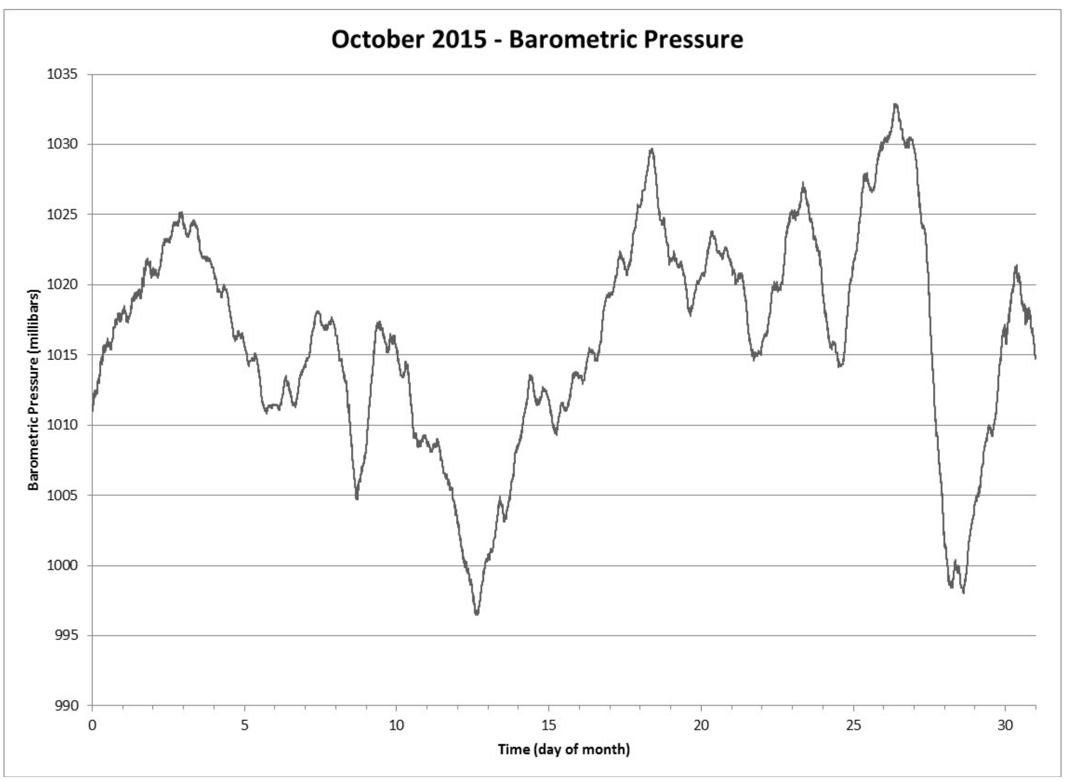

Figure 26 Barometric Pressure for the Month of October 2015

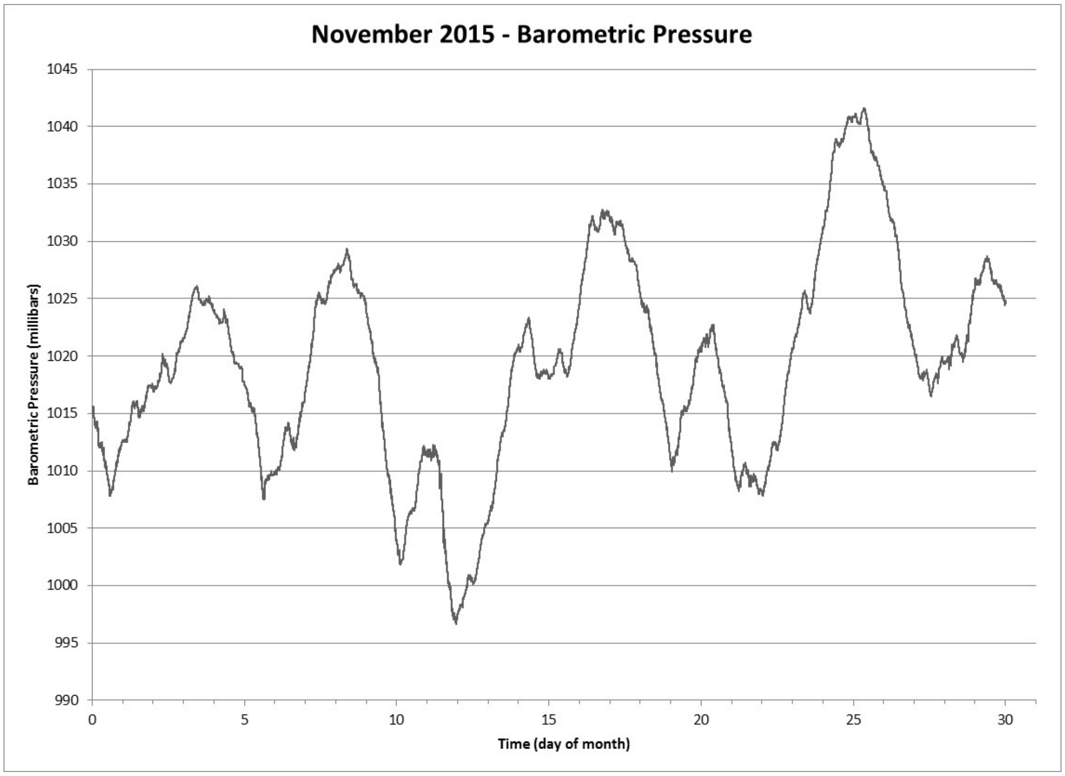

Figure 27 Barometric Pressure for the Month of November 2015

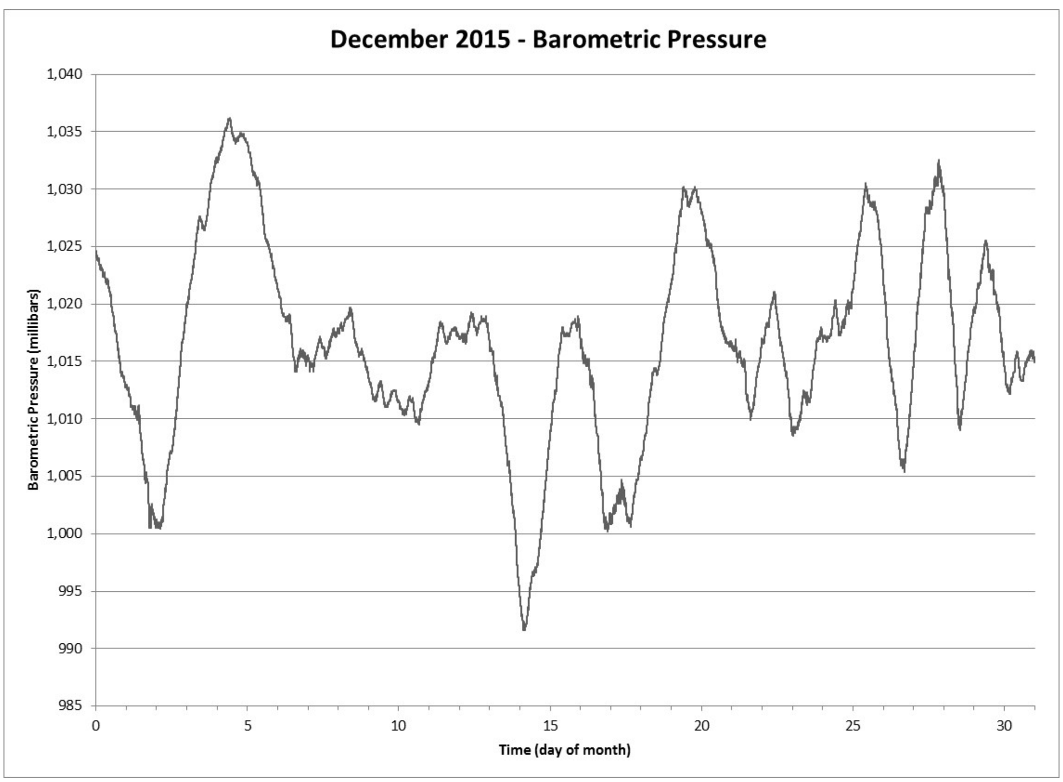

Figure 28 Barometric Pressure for the Month of December 2015

Relative Humidity

Relative Humidity is measured at the 2-meter level. The sensors are calibrated on site and maintained to ±4%. The relative humidity sensor is calibrated, in the laboratory, using saturated salt baths. The use of saturated salt baths is one of the oldest methods for generating humidity at different levels. The RH value is a function of the chemical properties of the salt when mixed with water, with different saturated salt solutions yielding different RH values. Although cumbersome, saturated salt solutions are very reliable. The saturated salt solutions are easy to make and result in a fairly constant humidity over a reasonable temperature range. BNL Met Services uses saturated aqueous salt solutions as described in ASTM E104-02 to obtain a three point calibration of the RH probes. Specific humidity calibration chamber covers that fit each probe type are used and separate chambers for each salt solution. The reference solutions are stored in sealed chambers. The specific solutions include; Sodium Chloride (NaCl) for 75.5 ±0.2 % RH @ 20°C, Sodium Bromide (NaBr) for 59.1 ± 0.5 % RH @ 20° and Magnesium Chloride (MgCl) for 33.1 ±0.2 % RH @ 20°C. In contrast, the Campbell (Rotonic) HC2-S3 has a stated accuracy of ±0.8% @ 23°C. The ANS requirement is ±4%. If the probe fails to meet the ±4% it must be replaced.

The average daily humidity at BNL for 2015 was 74.4 %. The average daily low humidity was 50.5 %. The average daily high humidity was 93.9 %. Daily average humidity is plotted in Figure 29, daily minimum in Figure 30 and daily maximum humidity in Figure 31. Monthly data plots of the 1-minute data for relative humidity are presented in Figures 32 through 43.

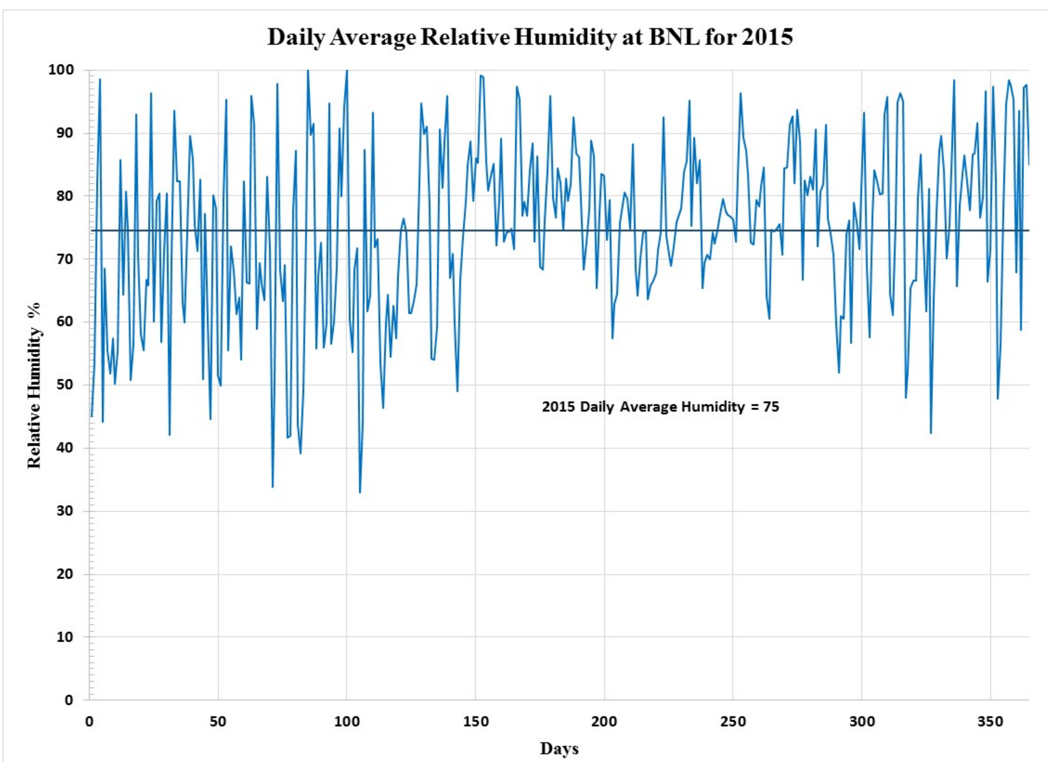

Figure 29 Daily Mean Relative Humidity at Brookhaven National Laboratory for 2015

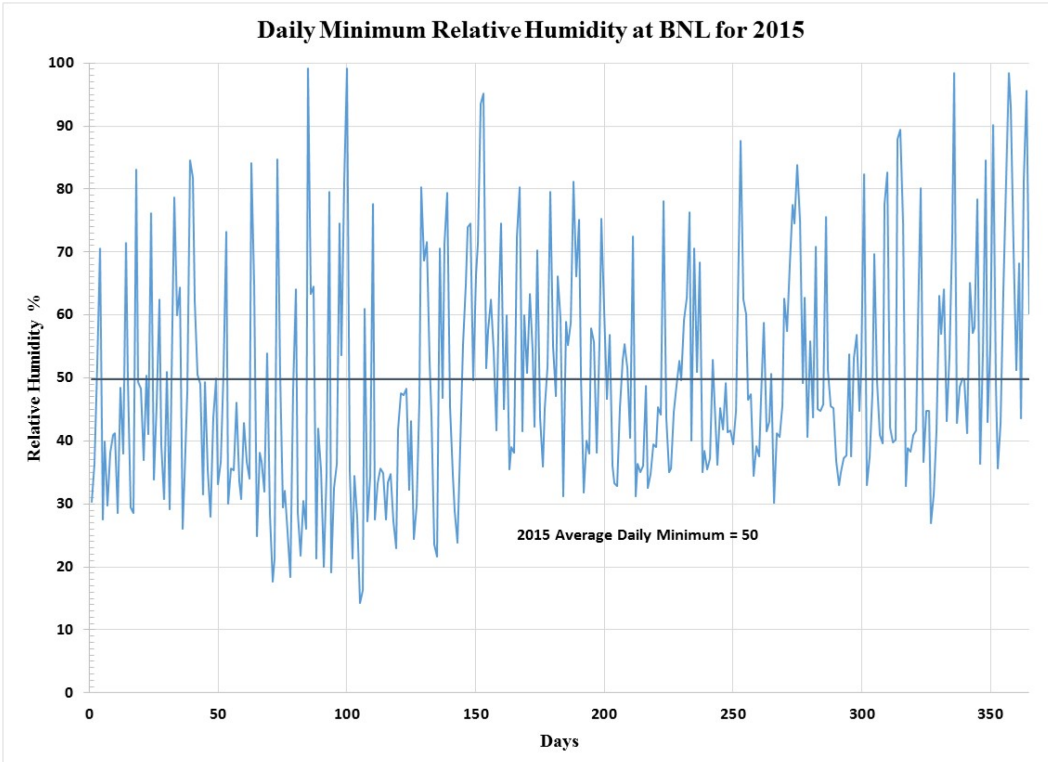

Figure 30 Minimum Daily Humidity at Brookhaven National Laboratory for 2015

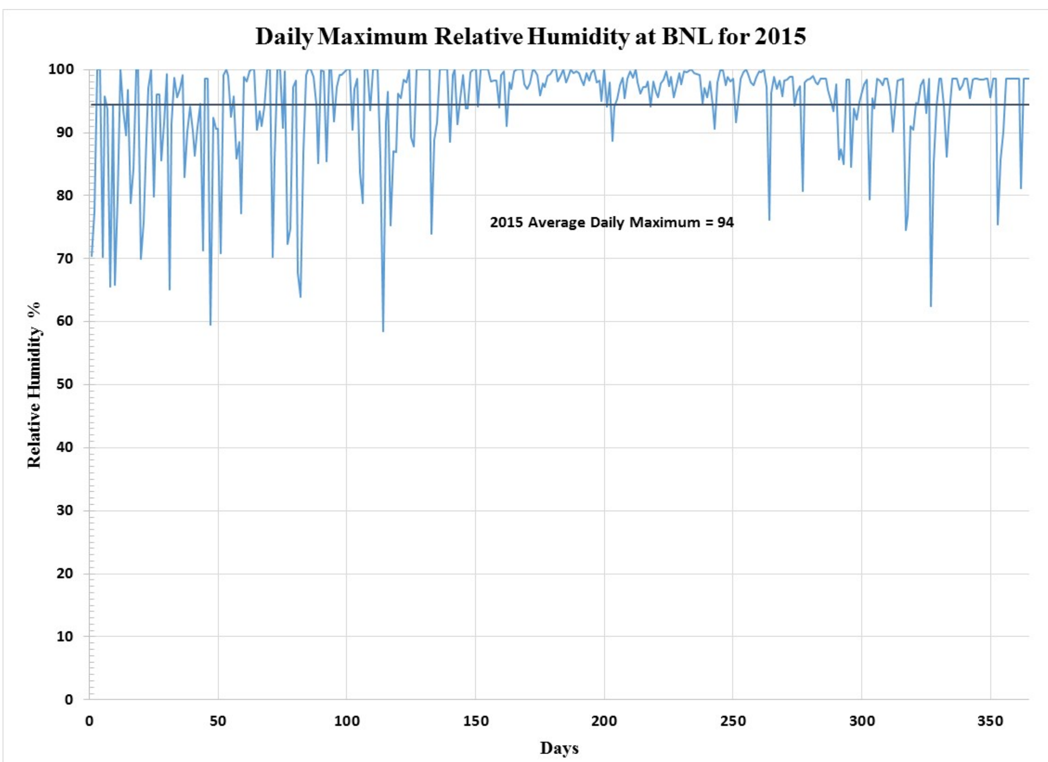

Figure 31 Maximum Daily Humidity at Brookhaven National Laboratory for 2015

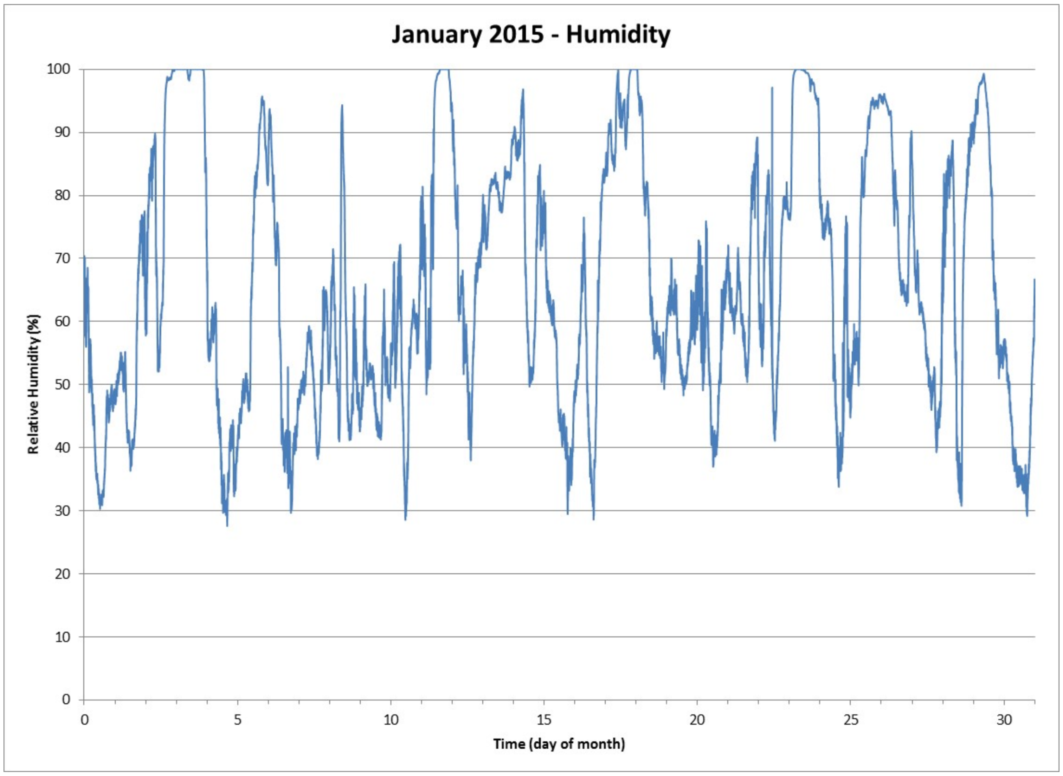

Figure 32 Relative Humidity for the Month of January 2015

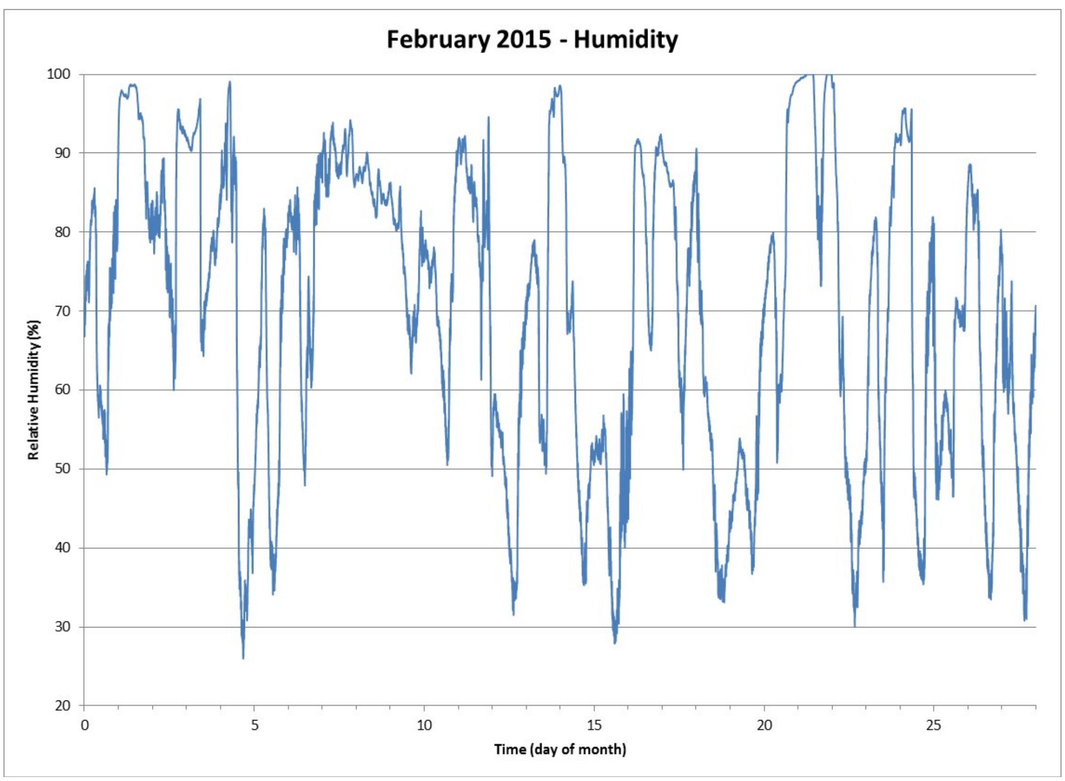

Figure 33 Relative Humidity for the Month of February 2015

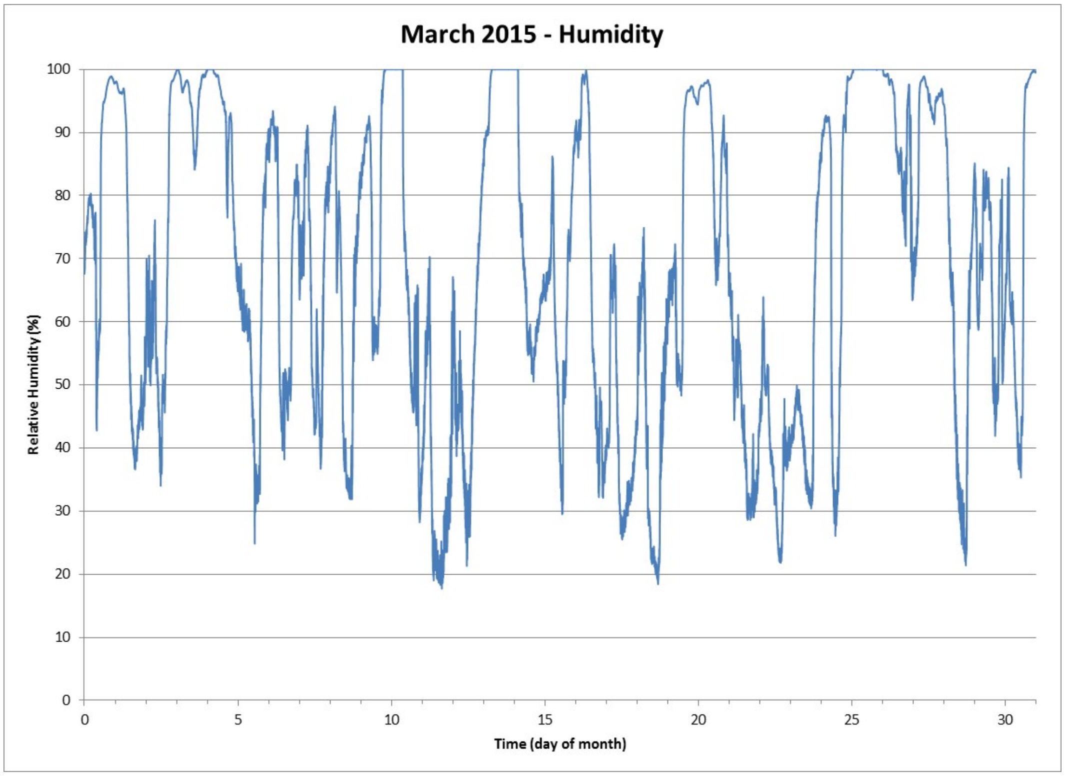

Figure 34 Relative Humidity for the Month of March 2015

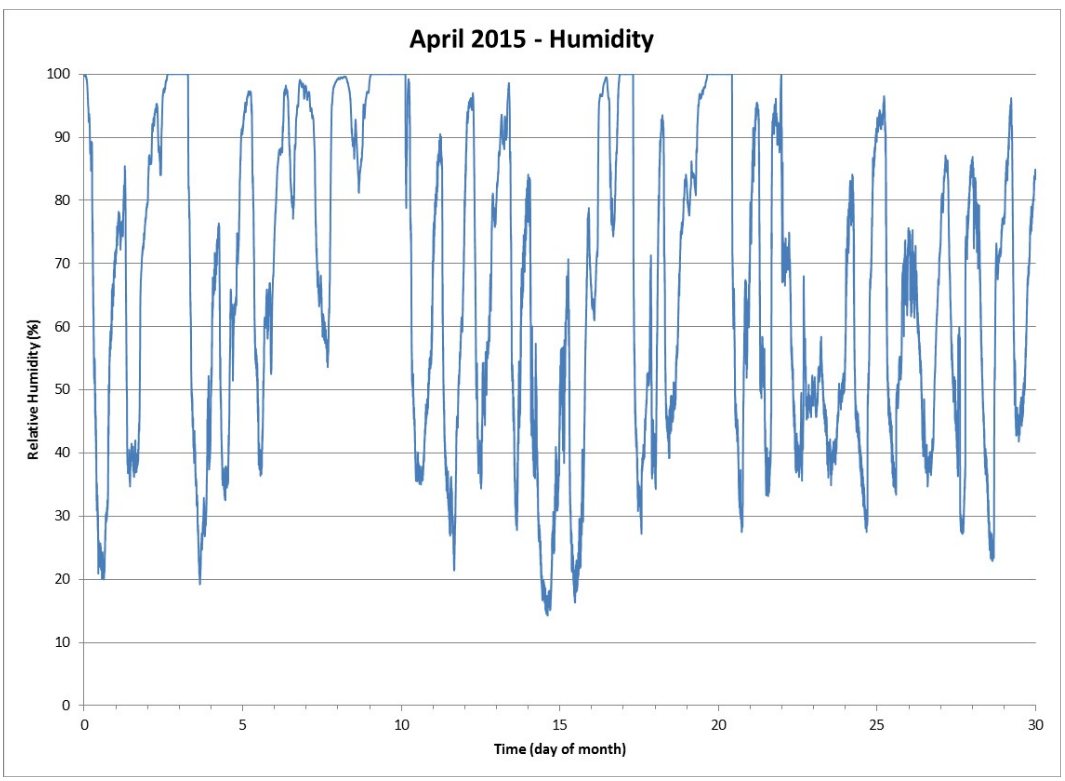

Figure 35 Relative Humidity for the Month of April 2015

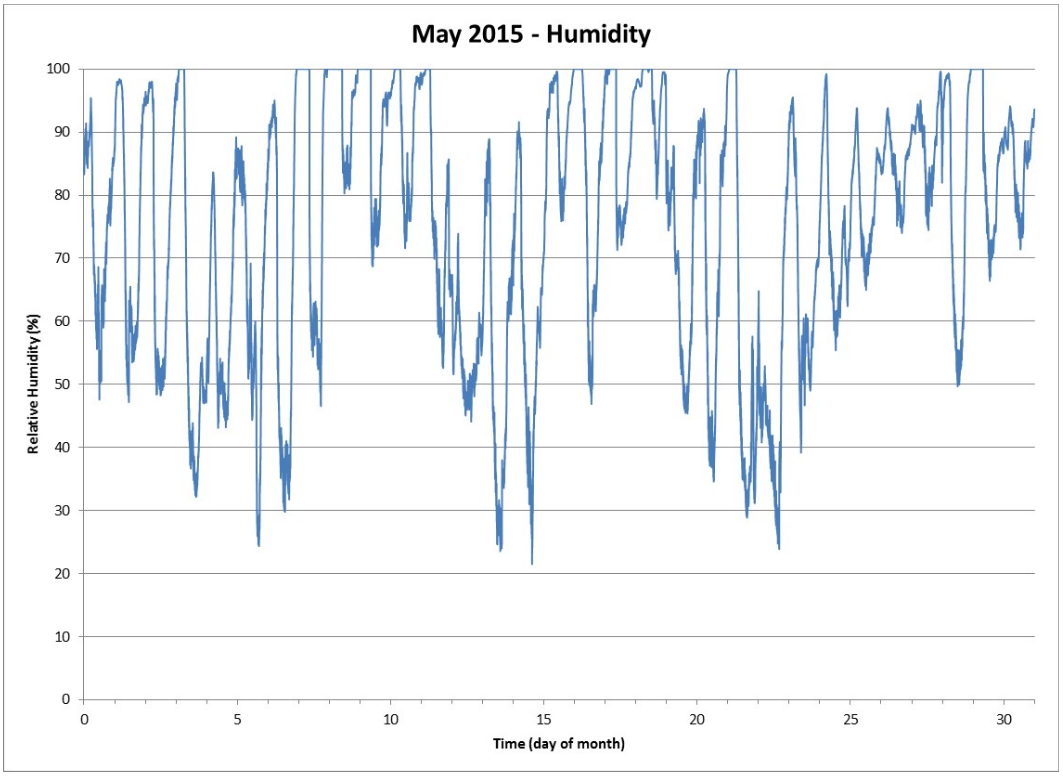

Figure 36 Relative Humidity for the Month of May 2015

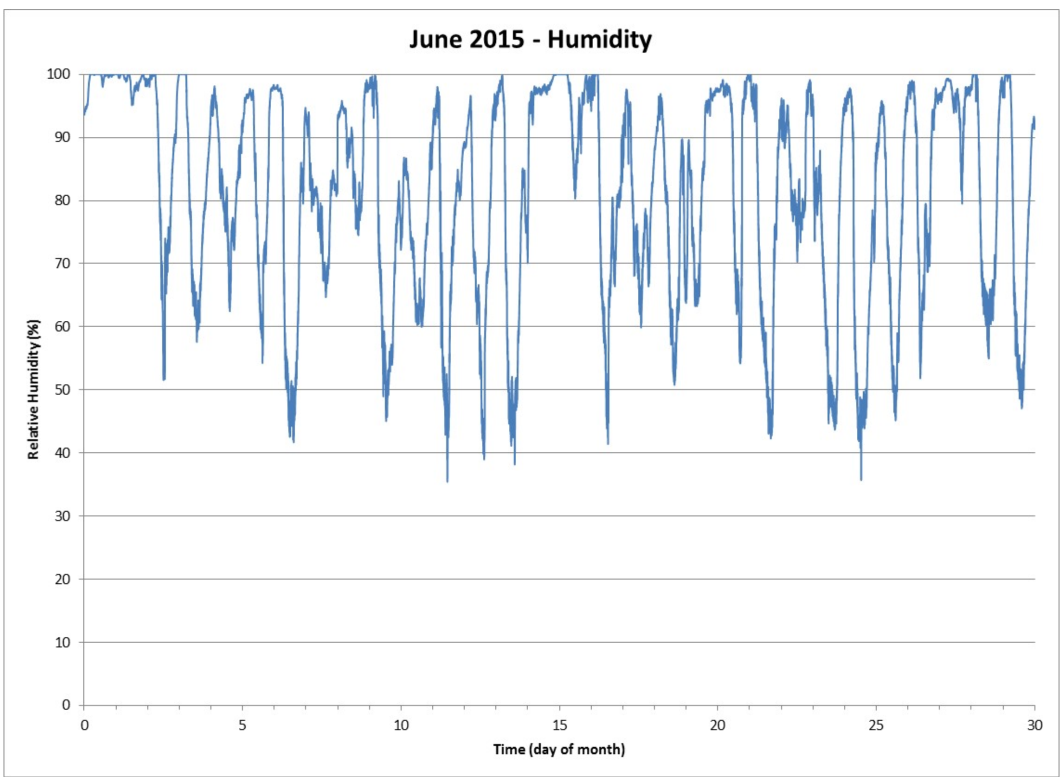

Figure 37 Relative Humidity for the Month of June 2015

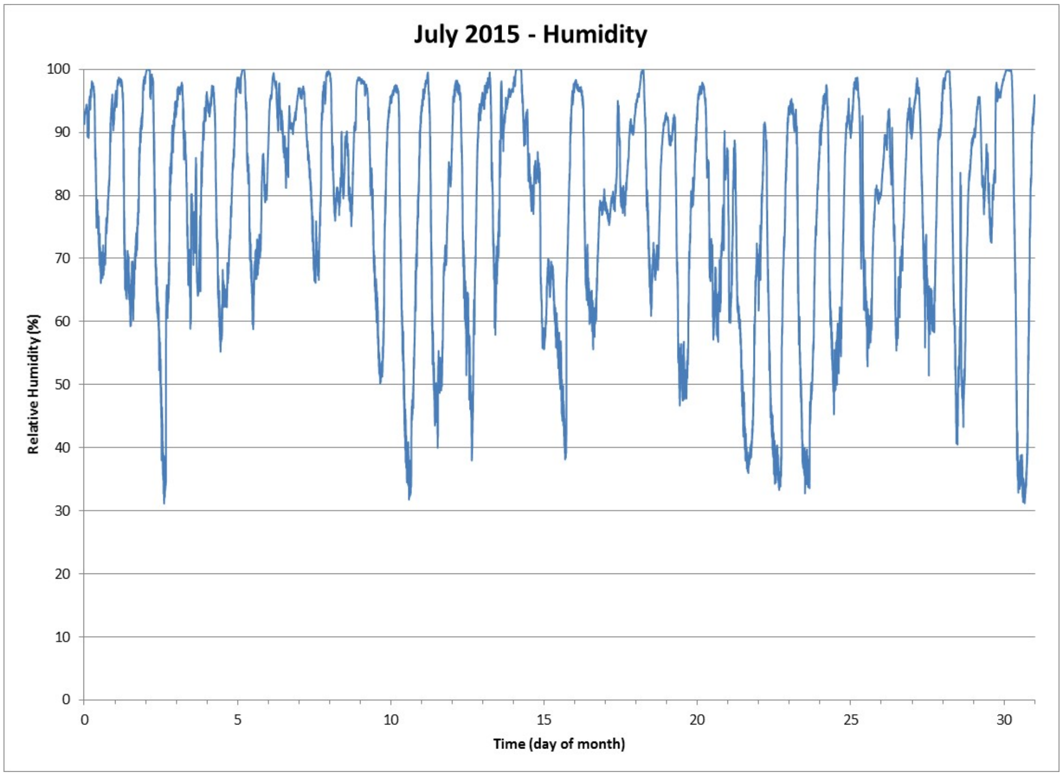

Figure 38 Relative Humidity for the Month of July 2015

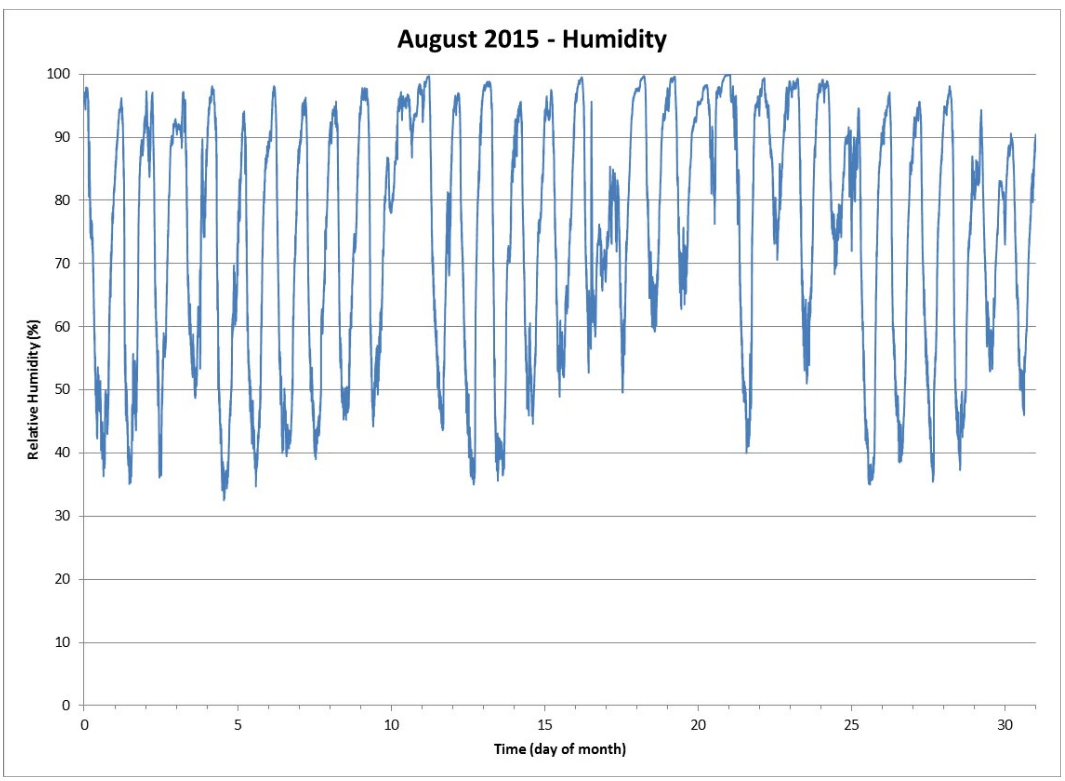

Figure 39 Relative Humidity for the Month of August 2015

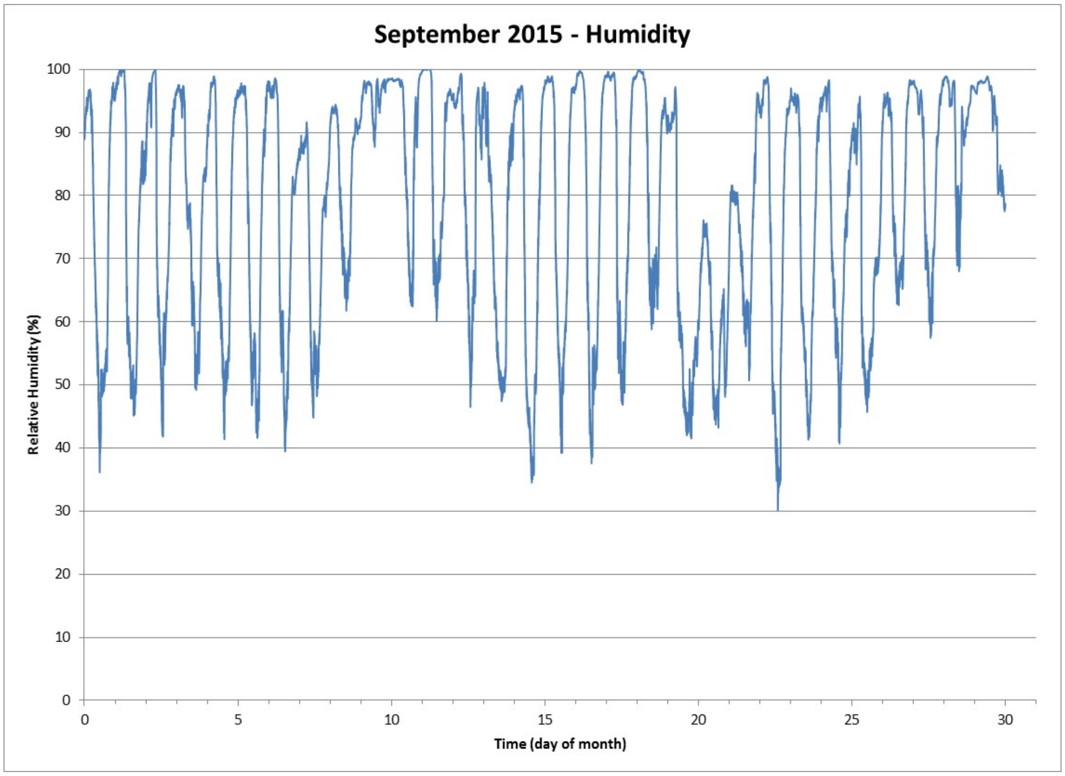

Figure 40 Relative Humidity for the Month of September 2015

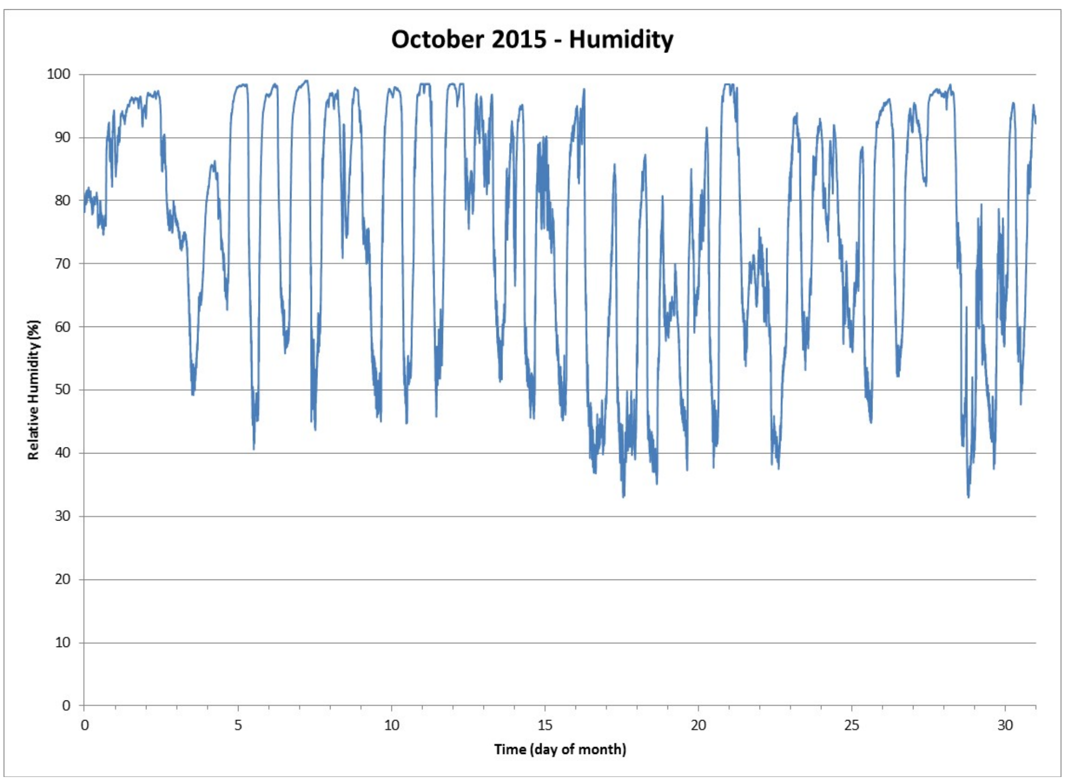

Figure 41 Relative Humidity for the Month of October 2015

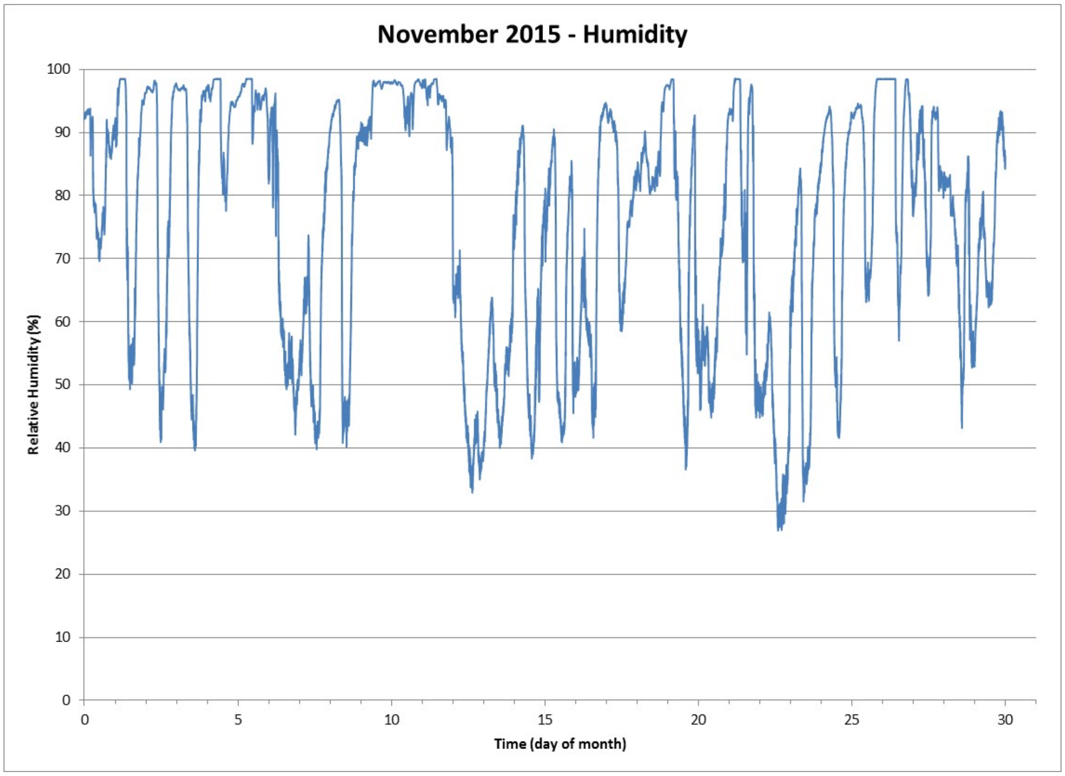

Figure 42 Relative Humidity for the Month of November 2015

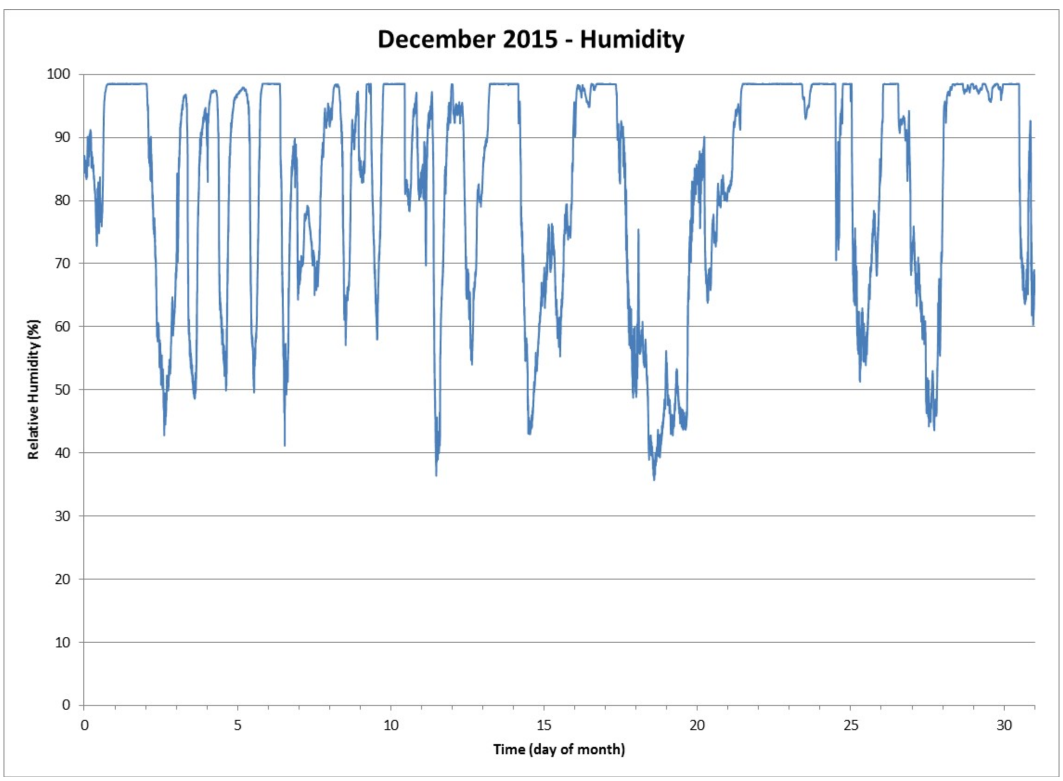

Figure 43 Relative Humidity for the Month of December 2015

Rainfall

Rainfall is measured using a 12" NovaLynx 2500 electrically heated (for snowfall events), tipping bucket rain gauges which are calibrated annually. The gauges measure tips for each 0.01" of rain. Calibration is accomplished by BNL personnel using the NovaLynx Calibration Assembly (model 260-2595) and is completed in-situ. Accuracy is ±1% for 1 to 3 inches per hour rainfall and ±3% for 0 to 6 inches per hour. If the test results are outside this accuracy requirement the tipping bucket is adjusted to bring it within specs. Daily rainfall totals for 2012 are depicted in Figure 44. Monthly data charts of daily rainfall totals are presented in Figures 45 through 56. Table 6 lists the historic monthly rainfall totals along with monthly averages, maximums and minimums from 1949 to 2015.

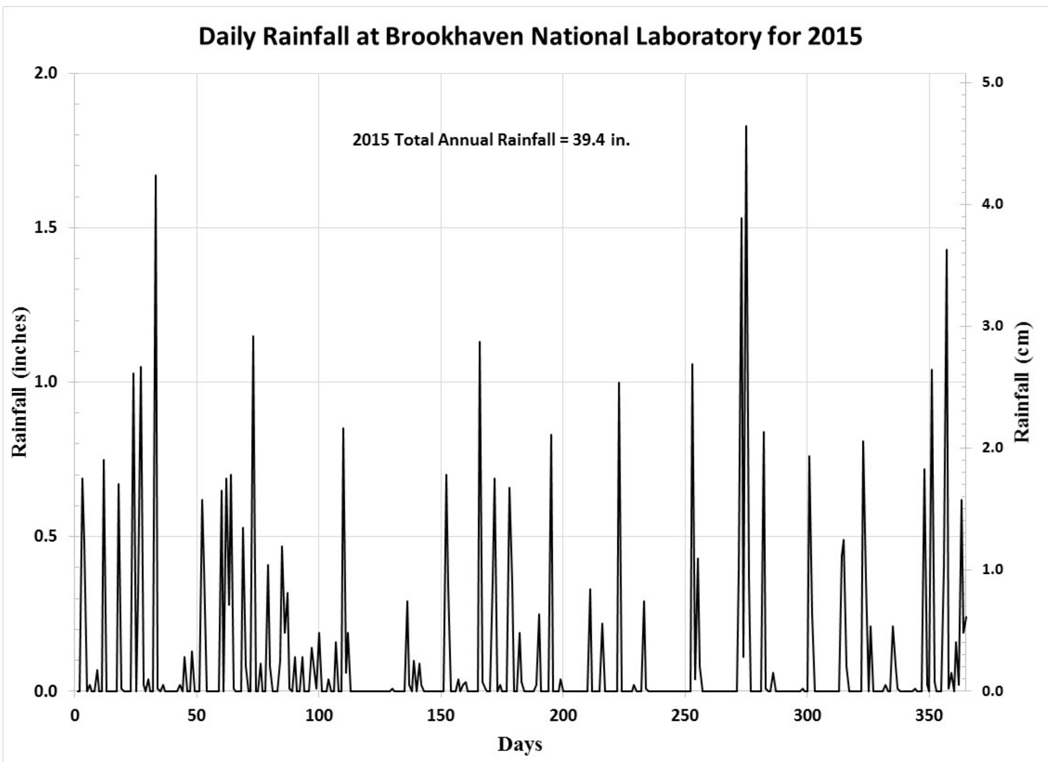

Figure 44 Daily Rainfall Totals at Brookhaven National Laboratory for 2015

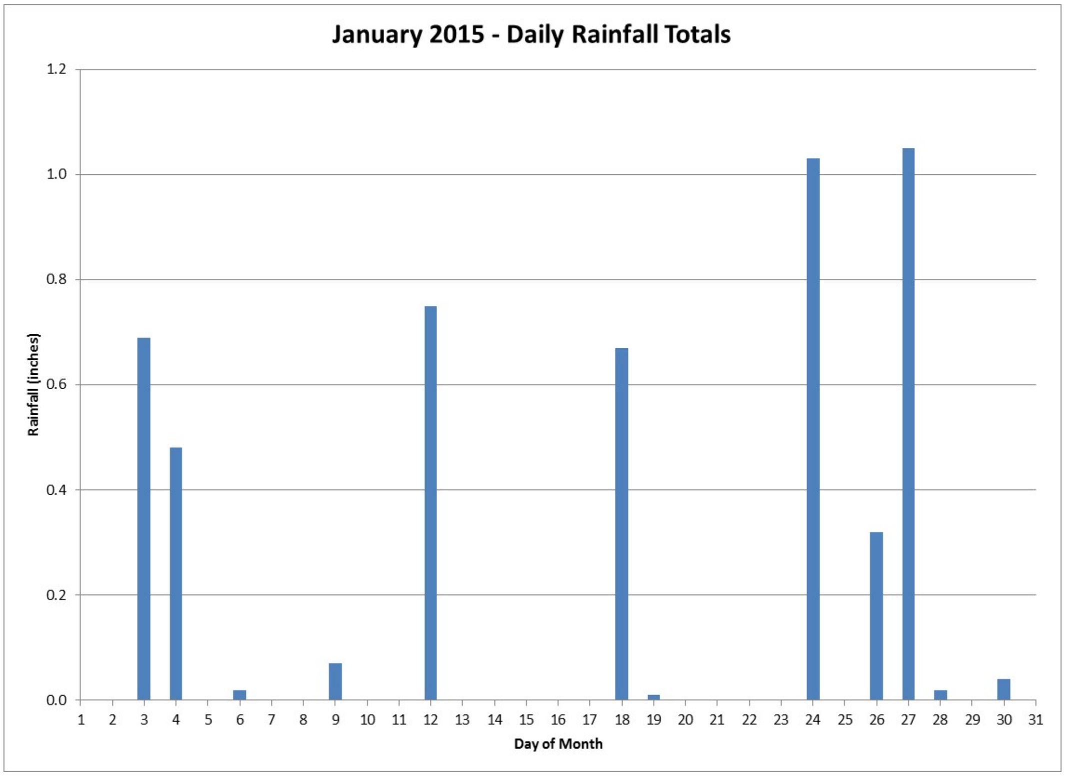

Figure 45 Daily Rainfall for the Month of January 2015

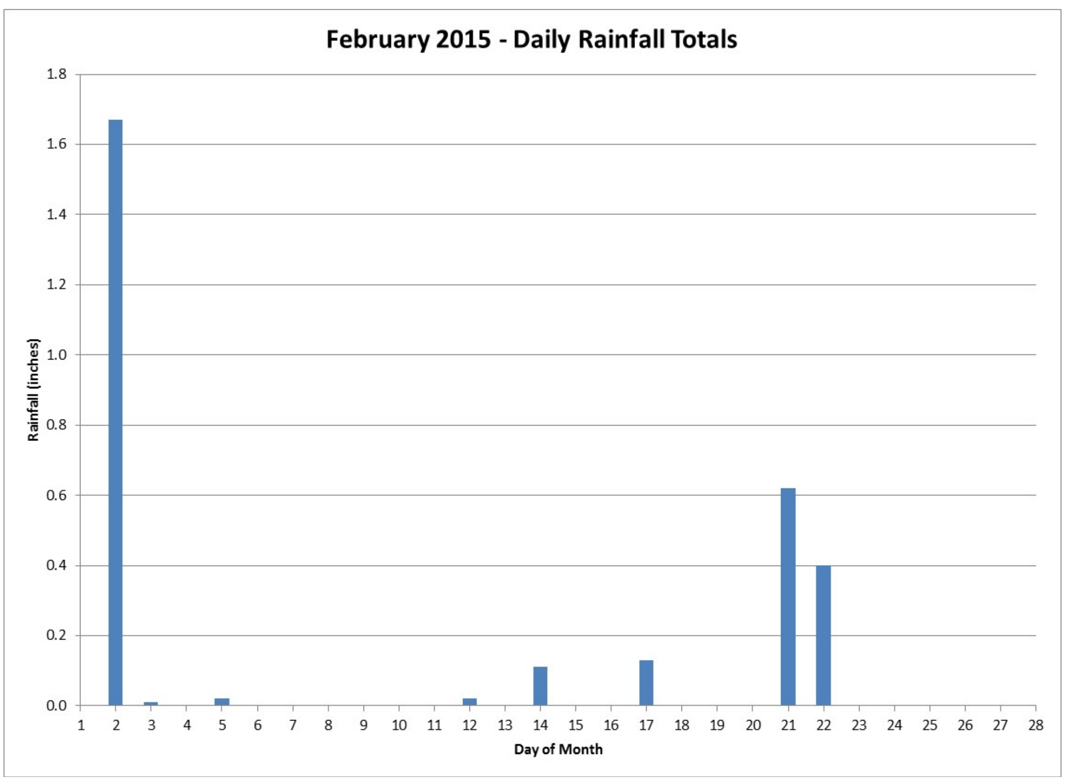

Figure 46 Daily Rainfall for the Month of February 2015

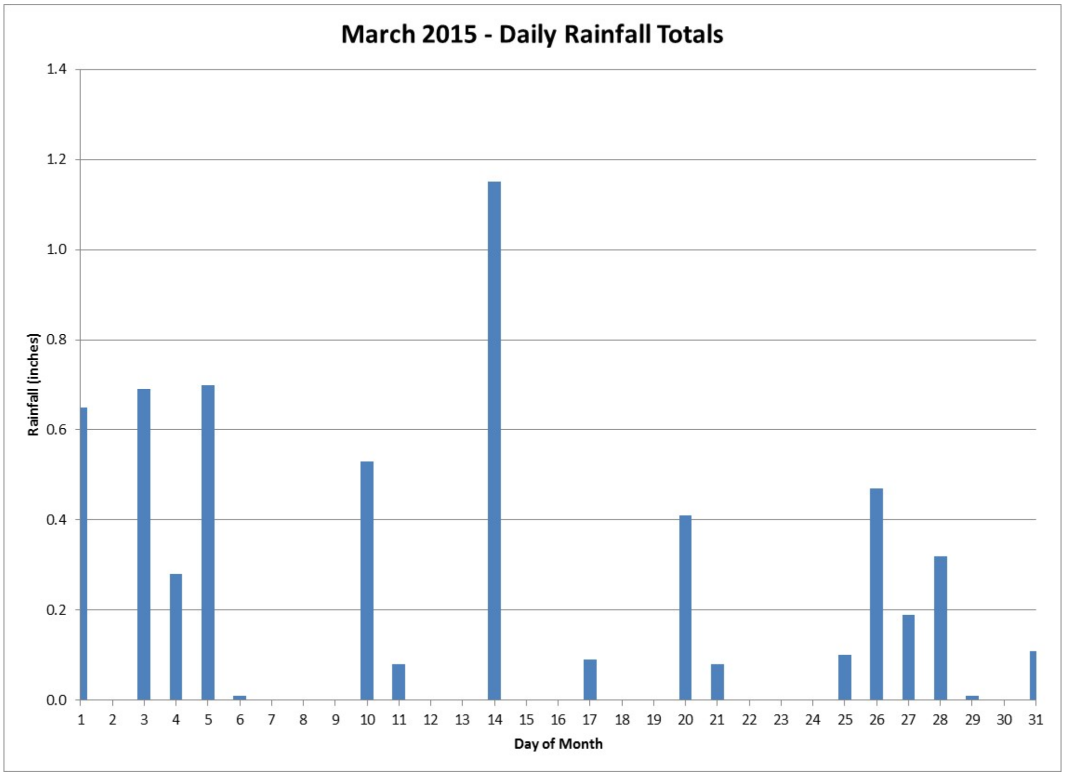

Figure 47 Daily Rainfall for the Month of March 2015

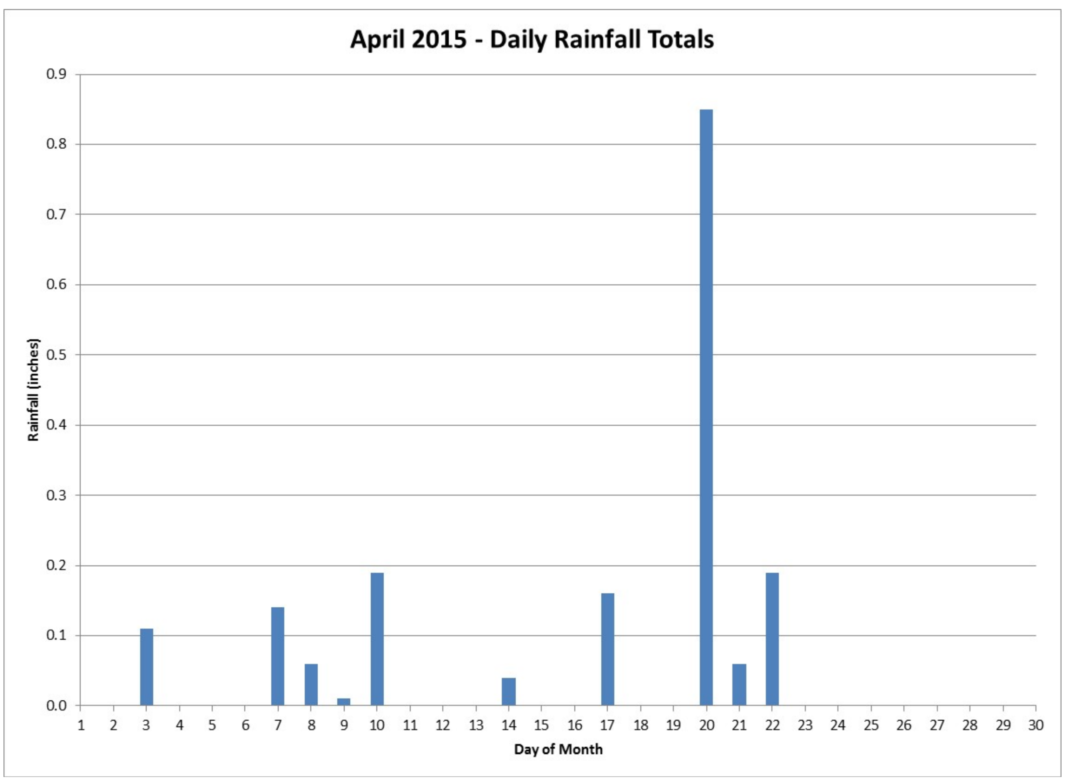

Figure 48 Daily Rainfall for the Month of April 2015

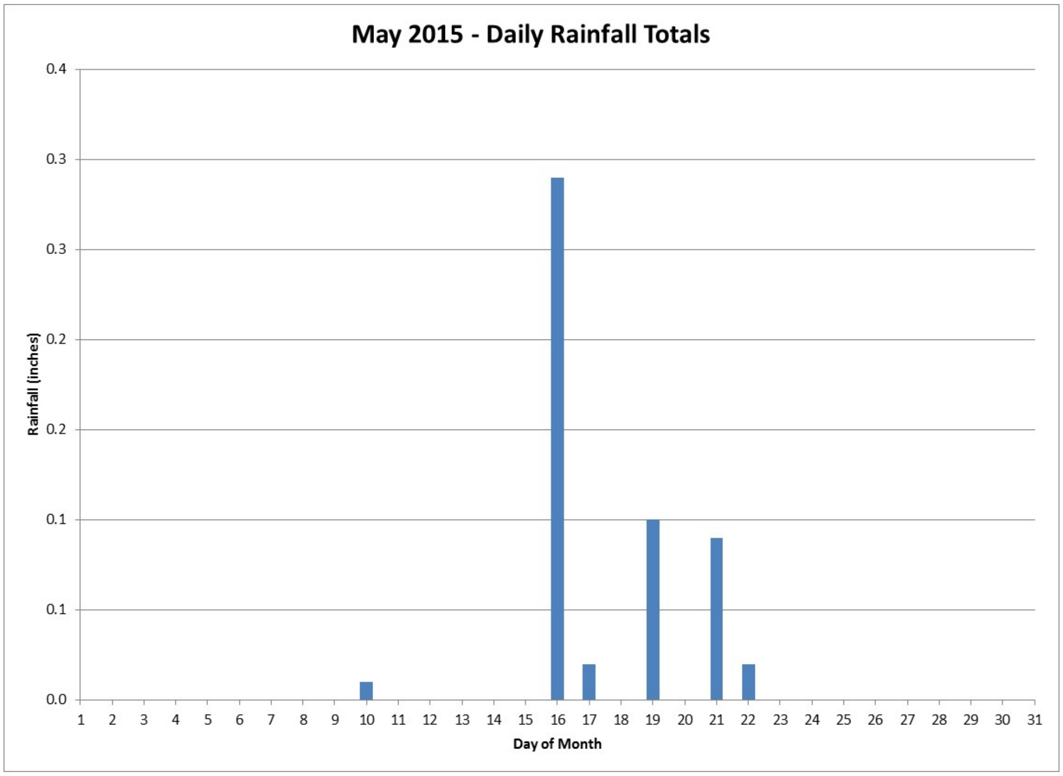

Figure 49 Daily Rainfall for the Month of May 2015

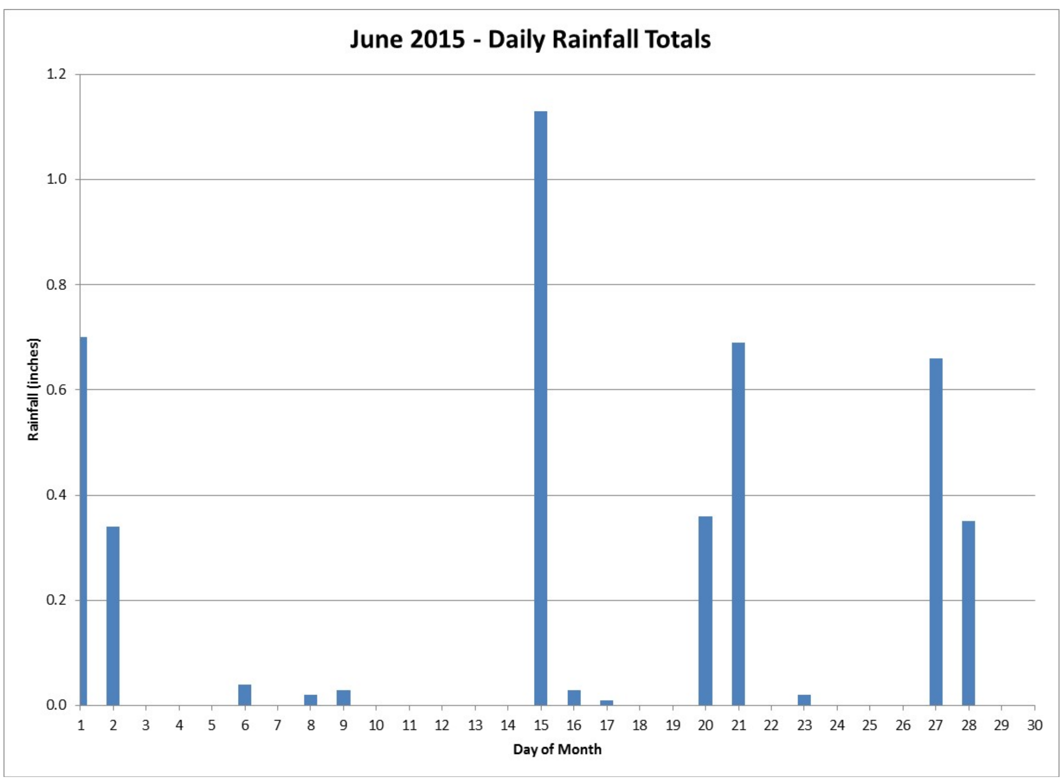

Figure 50 Daily Rainfall for the Month of June 2015

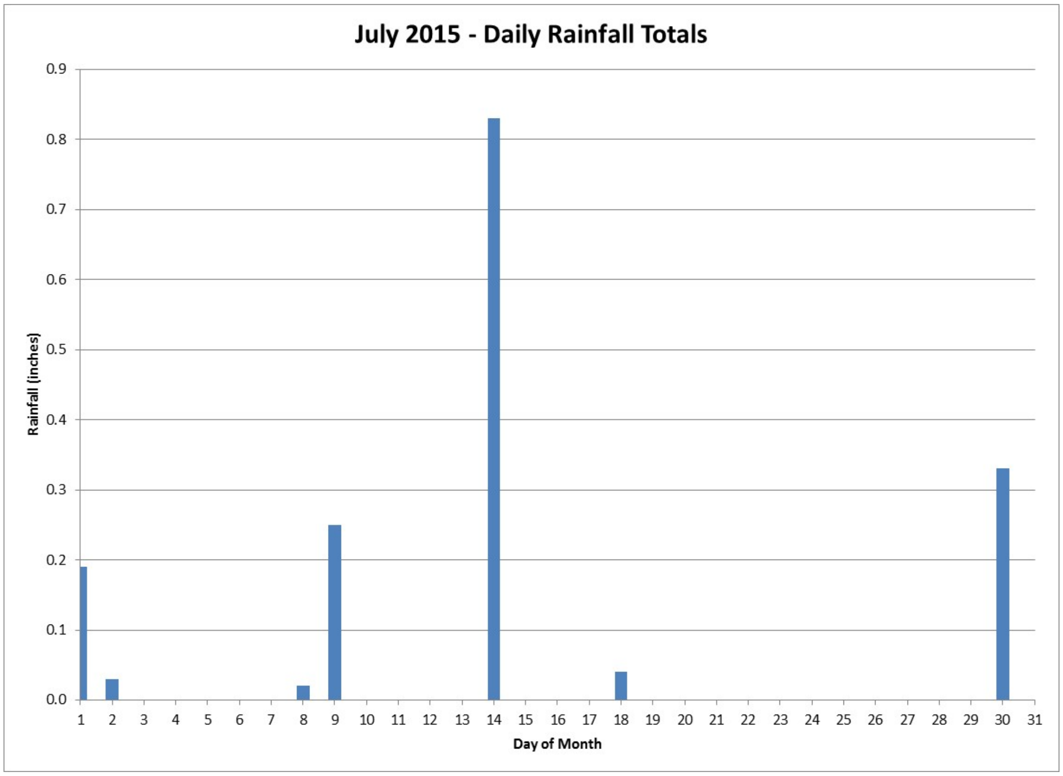

Figure 51 Daily Rainfall for the Month of July 2015

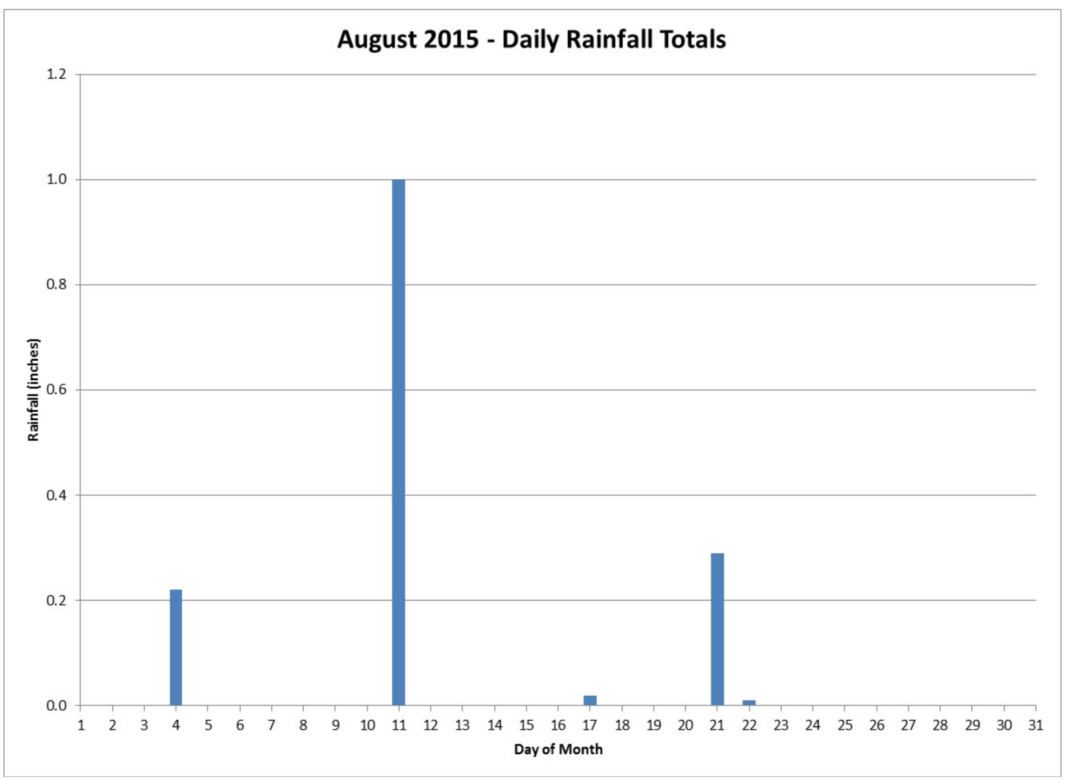

Figure 52 Daily Rainfall for the Month of August 2015

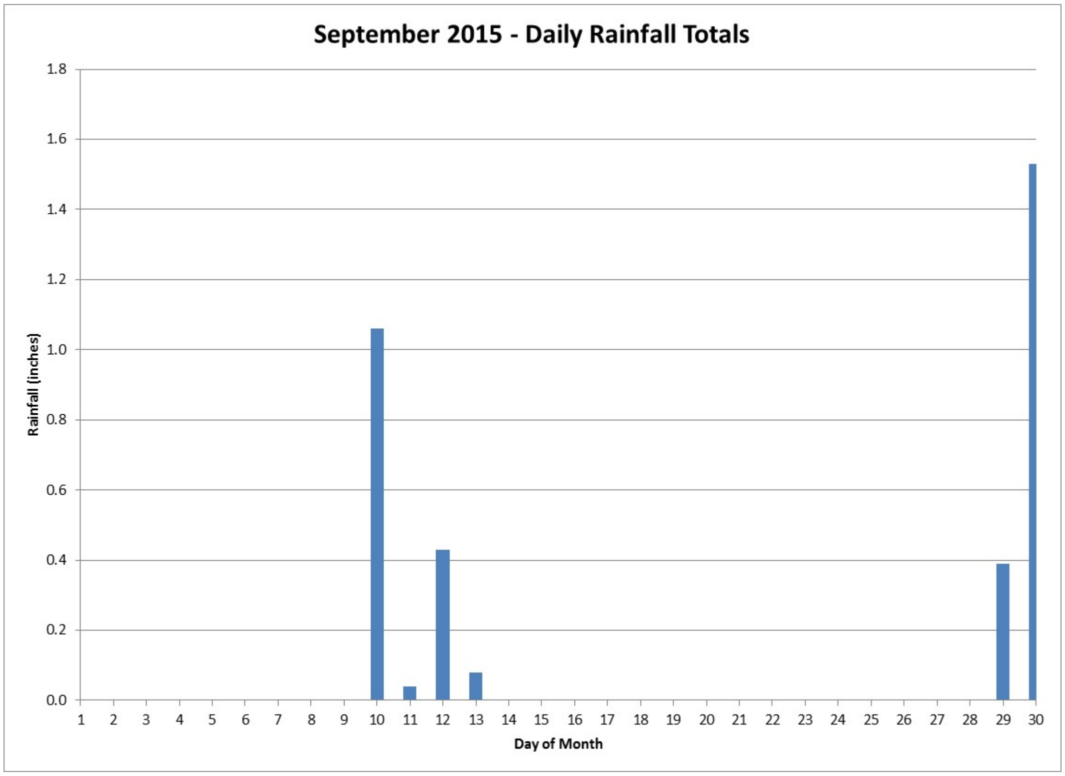

Figure 53 Daily Rainfall for the Month of September 2015

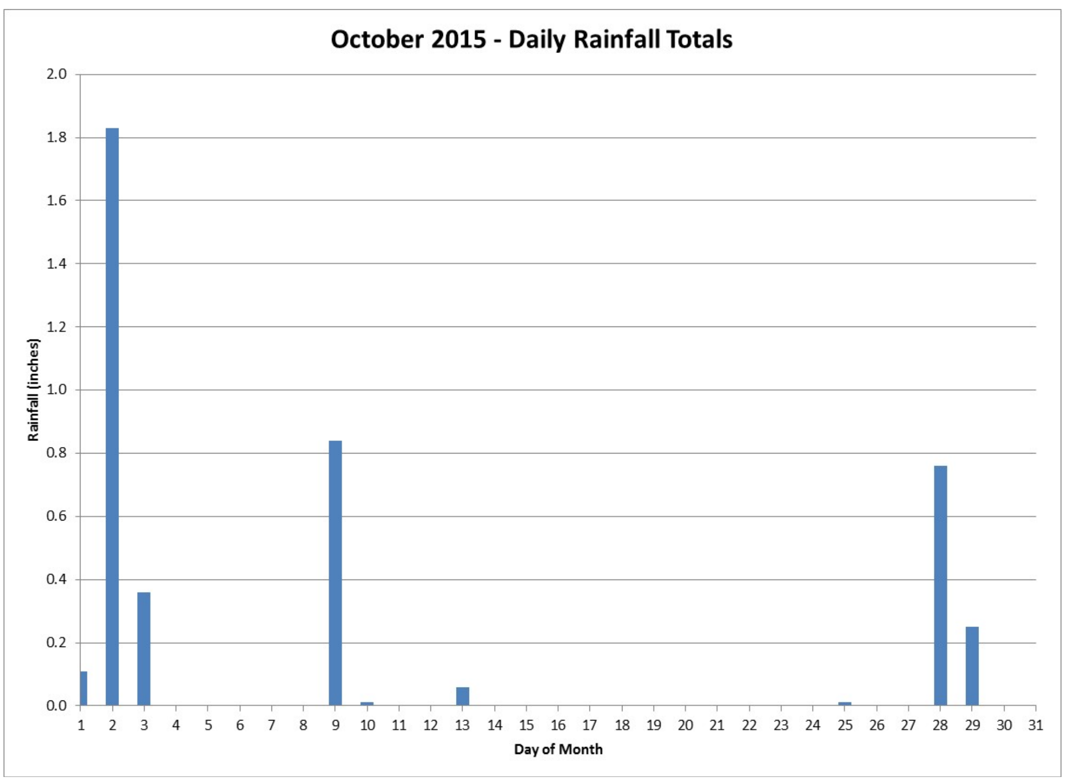

Figure 54 Daily Rainfall for the Month of October 2015

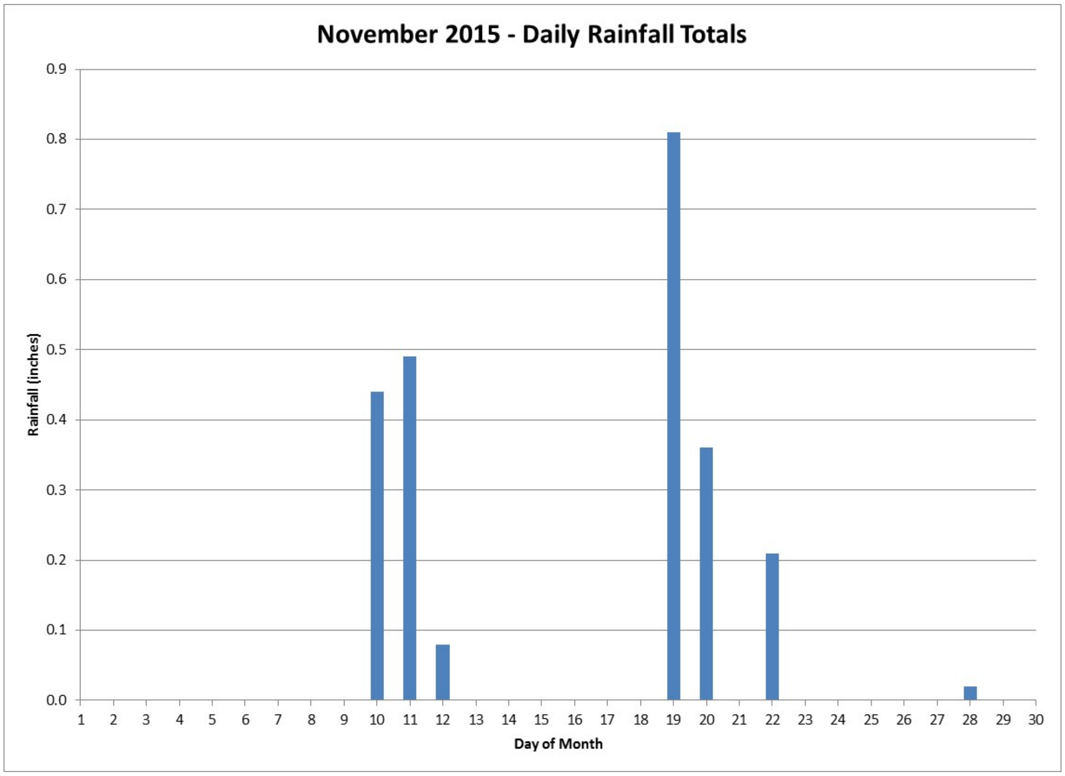

Figure 55 Daily Rainfall for the Month of November 2015

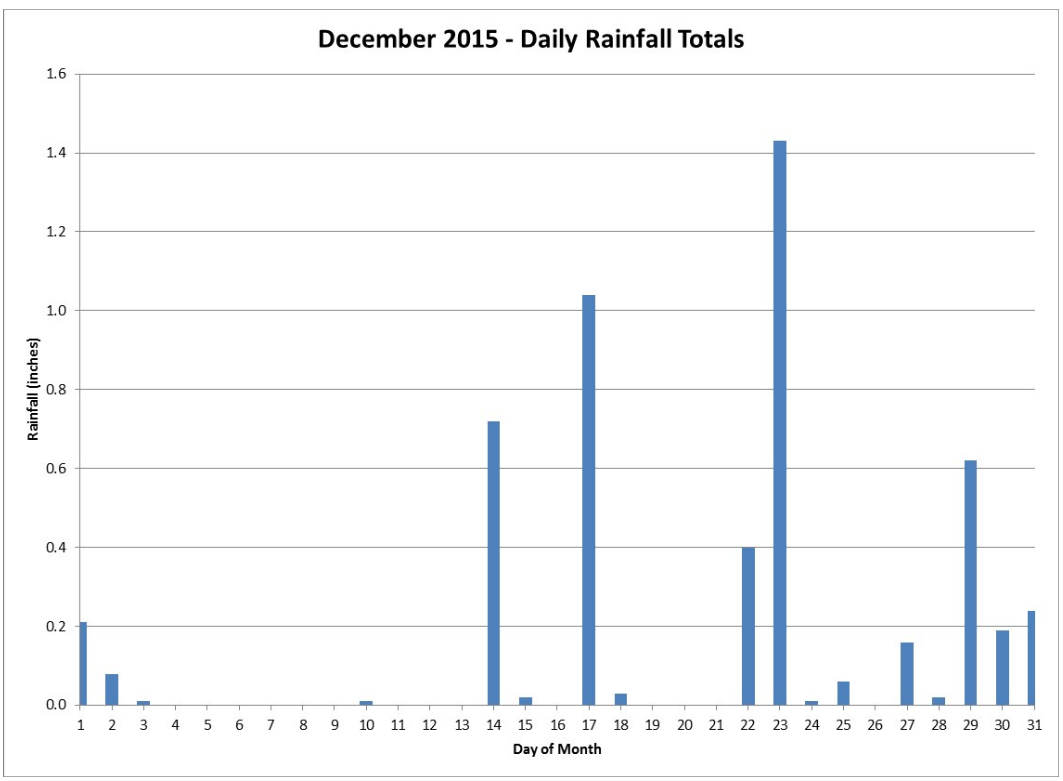

Figure 56 Daily Rainfall for the Month of December 2015

Table 6. Historic Monthly Precipitation for Brookhaven National Laboratory from 1949 to 2015 (@ 2 meters)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	5.55	4.71	2.88	3.63	3.32	Trace	3.07	5.21	3.49	1.74	2.96	3.36	39.92
1950	2.80	4.28	3.98	2.41	5.23	2.72	3.22	4.26	1.38	1.69	4.34	4.36	40.67
1951	3.75	4.99	5.02	3.42	3.68	2.64	2.08	4.50	1.06	5.48	6.01	6.17	48.80
1952	7.10	3.54	5.44	3.61	7.64	2.78	1.00	7.61	1.35	0.31	3.56	4.45	48.39
1953	6.73	4.16	10.36	5.59	3.34	1.66	2.76	2.40	0.90	3.17	5.03	6.43	52.53
1954	2.74	2.18	4.21	5.36	4.08	1.69	0.94	**11.98**	**10.47**	2.44	5.42	6.39	57.90
1955	**0.62**	3.26	4.79	4.28	0.95	2.53	1.65	9.04	3.96	11.43	7.19	**0.82**	50.52
1956	3.52	6.32	5.47	2.97	2.63	3.00	5.79	1.50	3.64	2.95	4.63	6.03	48.45
1957	2.36	2.53	3.20	4.44	1.46	**0.42**	2.84	4.25	3.57	3.86	4.41	8.45	41.79
1958	7.96	4.58	6.65	6.34	5.81	2.28	3.42	5.37	4.24	7.39	2.88	2.68	59.60
1959	2.60	2.06	6.71	3.93	1.75	5.35	6.85	3.72	1.36	3.13	4.46	5.12	47.04
1960	3.59	5.48	3.38	3.27	2.54	2.13	6.03	1.79	7.49	3.94	2.62	4.31	46.57
1961	3.56	4.10	4.60	5.70	6.17	2.30	5.61	4.23	6.23	3.06	2.89	3.70	52.15
1962	4.38	5.77	3.63	3.31	1.12	3.55	1.64	7.64	4.07	4.62	5.04	2.83	47.60
1963	3.27	3.88	4.27	2.56	3.08	5.51	2.65	2.10	3.66	**0.18**	6.89	2.78	40.83
1964	5.89	4.76	3.56	8.37	**0.63**	1.41	4.40	1.16	3.02	4.29	3.07	6.63	47.19
1965	4.88	3.03	2.74	4.20	1.63	1.69	3.43	5.15	1.51	2.15	1.83	2.11	**34.35**
1966	4.57	5.18	1.73	2.13	6.55	1.40	1.12	3.23	6.53	4.45	2.89	4.15	43.93
1967	1.65	3.98	8.18	4.14	7.98	5.30	6.01	5.43	2.24	2.11	4.00	7.60	58.62
1968	3.00	2.21	7.54	2.00	4.95	4.24	**0.50**	3.10	2.08	3.01	8.09	8.22	48.94
1969	1.04	4.03	3.62	5.15	2.44	2.06	**8.62**	5.51	3.60	3.69	4.48	7.83	52.07
1970	0.81	4.37	5.44	4.57	3.44	1.77	3.10	6.08	2.42	1.41	6.52	3.73	43.66
1971	2.95	**6.45**	3.55	3.30	3.80	0.92	5.03	3.86	2.12	3.41	6.86	2.57	44.82
1972	2.41	6.12	5.40	4.53	6.10	7.30	1.03	1.29	3.08	7.64	7.51	6.22	58.63
1973	4.44	4.36	4.38	7.77	5.46	3.25	4.45	3.11	2.51	2.79	2.22	8.00	52.74
1974	4.96	2.82	5.06	3.49	3.13	2.50	0.81	2.55	5.10	2.66	1.94	6.78	41.80
1975	6.50	4.06	4.27	3.89	3.45	5.37	3.33	2.01	5.58	3.61	5.89	4.92	52.88
1976	5.98	3.57	3.30	2.27	3.89	3.27	4.32	7.57	2.07	5.42	**0.54**	2.96	45.16

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1977	3.09	2.46	5.47	4.28	2.04	4.31	1.51	5.49	5.73	6.12	6.39	6.93	53.82
1978	10.72	2.60	3.33	2.39	6.47	0.81	4.63	5.22	4.26	4.11	2.79	6.12	53.45
1979	**13.01**	5.27	3.53	4.96	4.09	2.15	0.61	7.76	3.20	4.57	3.95	3.02	56.12
1980	2.02	1.18	7.20	6.16	1.52	3.60	1.92	1.56	0.98	3.59	4.20	1.06	34.99
1981	1.15	5.16	1.80	4.59	2.17	3.14	2.69	0.96	5.17	4.49	3.16	5.55	40.03
1982	7.20	2.90	3.38	5.44	1.71	**12.85**	1.77	3.45	1.40	2.07	3.87	2.38	48.42
1983	4.07	4.36	8.68	**11.09**	4.22	2.63	4.20	4.48	2.09	3.67	8.68	5.67	63.84
1984	2.87	6.38	6.92	5.41	8.08	6.68	7.06	1.02	4.16	3.20	2.40	2.98	57.16
1985	1.07	1.82	2.62	1.56	4.87	6.38	2.30	4.89	1.54	1.53	6.85	1.10	36.53
1986	3.96	3.46	3.17	2.35	1.09	1.66	5.02	5.69	**0.86**	2.25	6.72	7.50	43.73
1987	6.74	1.21	5.95	4.32	1.83	1.86	1.48	4.38	4.05	2.22	3.55	3.20	40.79
1988	3.59	4.81	4.22	2.17	2.58	1.43	3.93	1.36	3.52	3.87	**9.05**	2.52	43.05
1989	2.23	4.09	5.20	4.66	**10.47**	7.24	5.84	9.17	4.45	8.90	5.16	1.25	**68.66**
1990	5.24	2.92	2.14	4.96	6.52	3.95	2.64	6.75	3.04	7.17	1.78	5.90	53.01
1991	4.41	1.86	5.45	4.30	2.78	1.87	2.11	9.19	4.45	2.61	1.80	4.30	45.13
1992	2.40	2.18	3.34	1.78	3.05	4.90	4.76	5.61	3.51	1.07	5.96	6.60	45.16
1993	2.47	4.10	7.11	3.81	1.71	1.37	1.84	1.61	4.36	4.69	3.72	6.11	42.90
1994	5.78	4.04	6.55	2.26	2.93	0.51	0.91	5.04	4.41	1.09	6.34	4.30	44.16
1995	2.93	3.74	1.53	2.52	2.79	3.12	1.78	**0.54**	4.91	5.97	5.83	3.74	39.40
1996	5.22	3.51	3.58	6.40	3.39	4.41	4.94	2.68	6.08	8.24	3.11	**8.66**	60.22
1997	3.82	2.64	5.10	4.21	2.67	2.16	2.21	3.33	1.27	2.55	5.42	4.66	40.04
1998	7.01	5.66	8.08	6.55	8.58	8.43	0.94	3.68	2.50	1.91	2.05	1.22	56.61
1999	8.85	4.81	5.32	2.35	2.41	1.04	2.12	8.71	5.90	4.78	2.58	2.85	51.72
2000	3.75	2.58	5.49	6.29	4.28	5.18	8.37	3.38	6.86	0.31	3.79	4.09	54.37
2001	3.28	2.63	10.37	2.03	4.22	6.46	3.47	4.68	4.04	1.04	0.74	2.59	45.55
2002	3.07	**1.16**	5.05	4.58	4.48	4.37	1.37	3.94	5.84	6.40	6.18	5.63	52.07
2003	2.48	5.74	5.99	5.11	6.07	12.28	2.38	5.19	5.22	4.80	3.63	4.22	63.11
2004	2.15	3.14	3.47	4.94	2.59	1.34	3.05	4.30	5.14	1.62	2.16	1.96	35.86
2005	3.32	2.10	2.47	2.53	2.36	1.48	2.16	0.87	1.09	**22.14**	5.00	4.60	50.12
2006	5.52	2.87	**0.89**	7.17	6.73	6.73	5.73	6.44	3.21	7.22	6.61	2.47	61.59

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2007	4.32	2.00	5.58	6.87	2.06	3.18	7.58	2.78	1.69	1.71	3.31	4.25	45.33
2008	2.36	5.84	5.90	4.04	3.66	2.28	1.97	3.07	9.31	4.02	3.82	4.37	50.64
2009	1.27	1.74	1.79	5.39	6.05	7.99	7.19	1.15	3.18	6.13	4.65	7.64	54.17
2010	2.15	6.01	**11.98**	**0.74**	3.88	1.64	6.70	2.21	4.56	3.08	2.91	4.08	49.94
2011	3.23	3.61	3.00	4.34	3.37	4.33	2.34	9.81	4.74	5.75	3.52	3.16	51.20
2012	3.01	1.27	1.11	3.81	4.53	7.74	8.26	4.57	3.49	3.24	2.49	7.30	50.82
2013	2.35	5.84	3.82	1.67	3.04	8.37	4.14	2.05	2.39	0.26	3.13	6.17	43.23
2014	2.90	5.63	6.73	4.86	4.82	2.35	2.58	3.67	2.66	5.23	5.79	7.03	54.25
2015	5.15	2.98	5.87	1.81	**0.53**	4.38	1.69	1.54	3.53	4.23	2.41	5.25	39.37
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average	4.03	3.80	**4.77**	4.23	3.87	3.73	**3.50**	4.35	3.71	4.01	4.33	4.59	48.78
Max	13.01	8.34	11.98	11.09	10.47	12.85	8.62	11.98	10.47	**22.14**	9.05	8.66	**68.66**
Min	0.62	1.16	0.89	0.74	0.53	0.42	0.50	0.54	0.86	**0.18**	0.54	0.82	**34.35**

Min **Max**

Wind Direction and Wind Speed

Wind speed and direction are recorded via R.M. Young 5106 marine grade mechanical wind sensor. This unit has a 0 to 100 m/s wind speed range and has been modified to have a 0.5 m/s wind speed threshold sensitivity. Accuracy is ±0.3 m/s. The direction sensor has a 355° electrical range and 360° mechanical. Direction accuracy is ±3° and sensitivity is 1.1 m/s (wind speed needed for accurate measurement). These units require a wind tunnel calibration and are sent out for calibration on an annual basis. Enough spare units are stocked to allow change out without data loss.

Average daily wind speed recorded at the 10-meter and 85-meter locations is given in Figure 57. Historic, Annual and Monthly wind roses are presented in Figures 58 through 85. A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. The wind rose data used in the plots are generated from hourly averages. Wind roses are presented for the 10- and 85-meter locations. Speed bins are 0.3 to 2.5 m/s, 2.5 to 5m/s, 5 to 7.5 m/s, 7.5 to 10 m/s and >10 m/s. Percent calm data (<0.3 m/s) and percent bad data are also listed. Prevailing winds at BNL are from the south-southwest with a secondary west-northwest component at the 85 meter level and west-northwest with a secondary south-southwest component at the 10 meter level.

Figures 86 through 109 present the 1-minute data for wind speed and wind gust. Plots contain data from 10-, 50- and 85-meters.

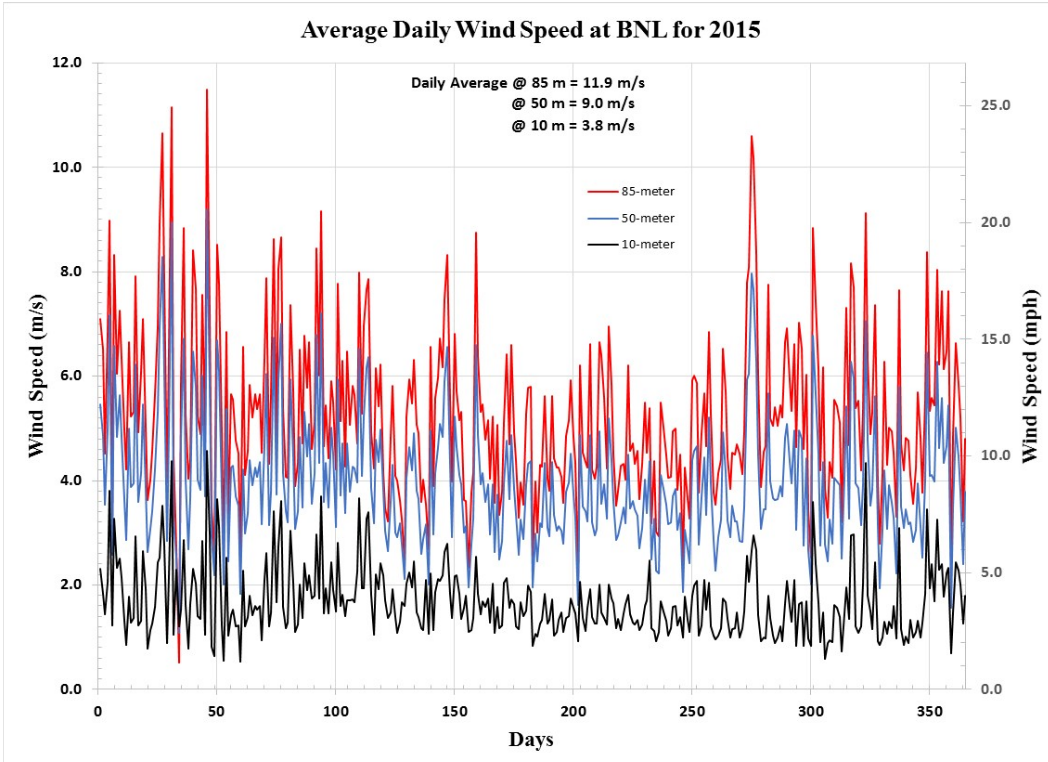

Figure 57 Average Daily Wind Speed (m/s) at the 10-meter, 50-meter and 85-meter heights at Brookhaven National Laboratory for 2015

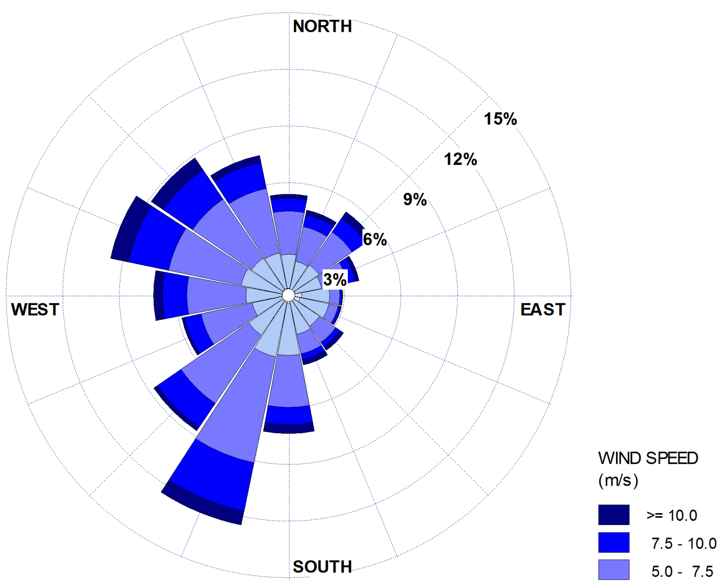

Figure 58 Historic Annual One-hour Wind Roses for the Years 1994 to 2015 from the 85m level

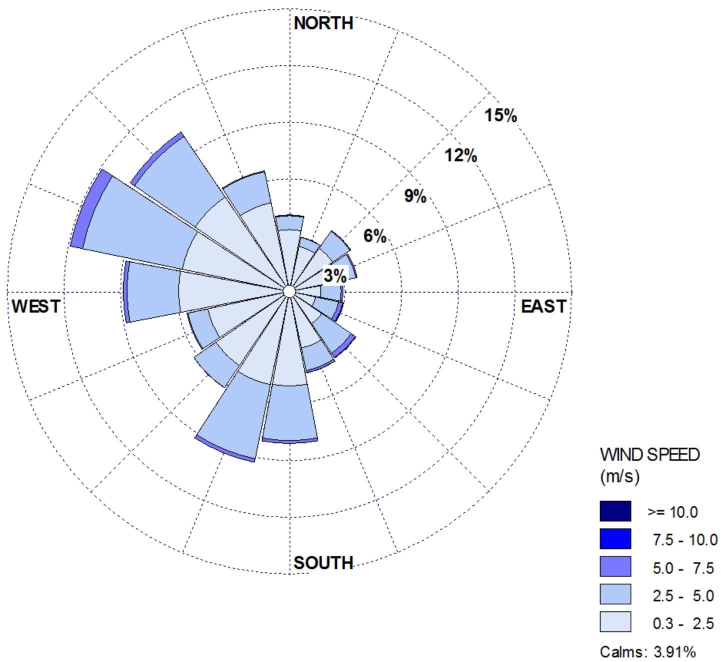

Figure 59 Historic Annual One-hour Wind Roses for the Years 1994 to 2015 from the 10m level

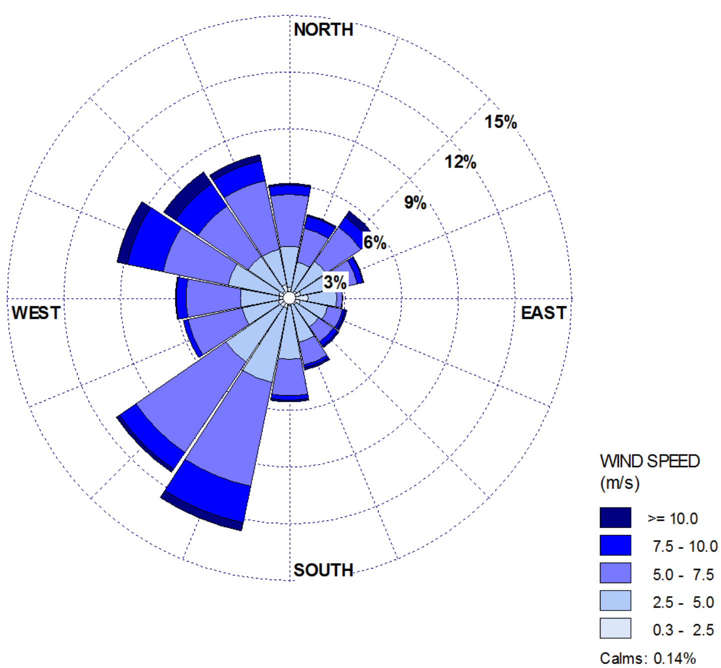

Figure 60 Annual One-hour Wind Roses for the Year 2015 from the 85m level

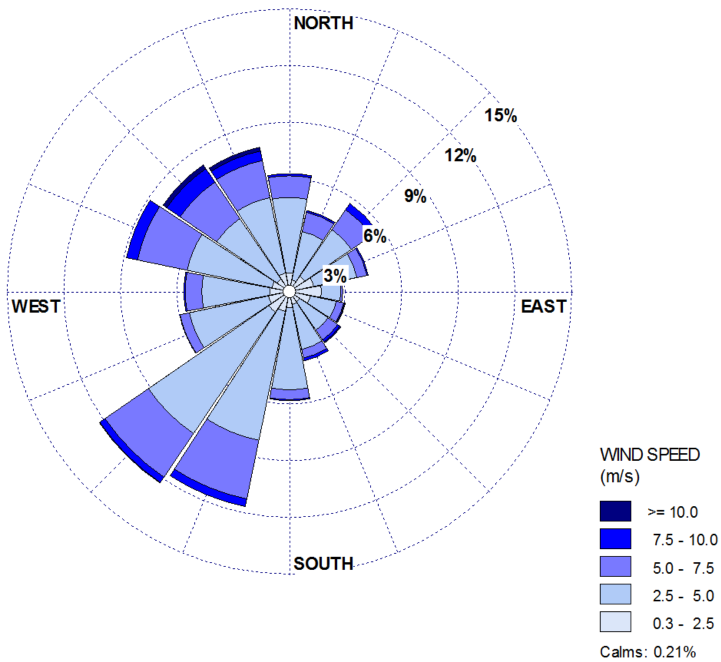

Figure 61 Annual One-hour Wind Roses for the Year 2015 from the 50m level

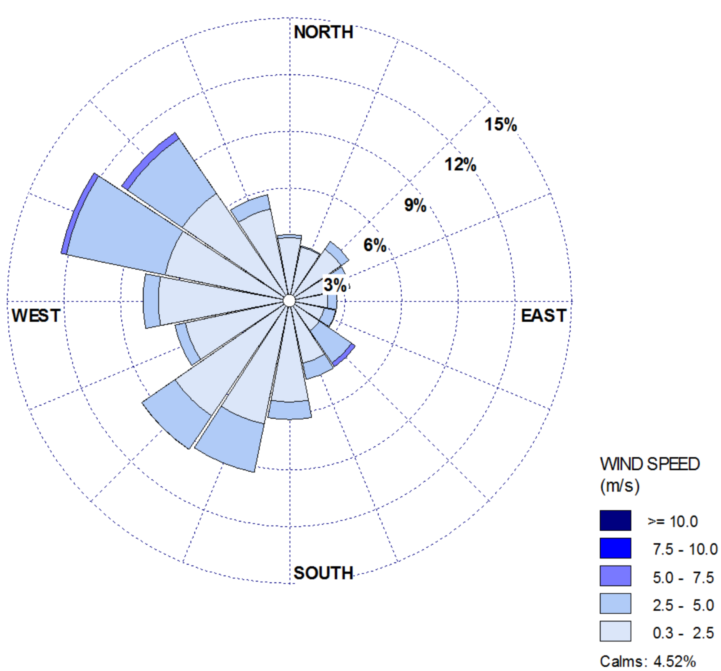

Figure 62 Annual One-hour Wind Roses for the Year 2015 from the 10m level

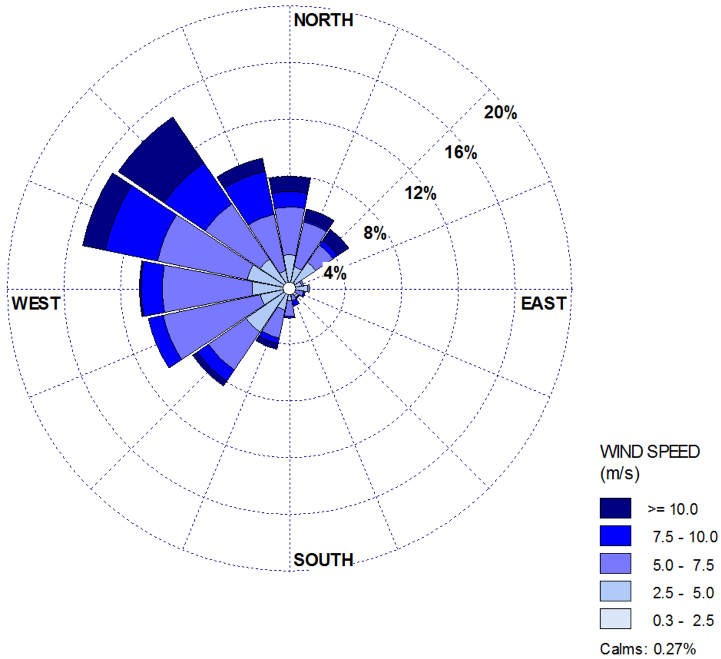

Figure 63 One-hour Wind Roses for the Month of January 2015 from the 85m level

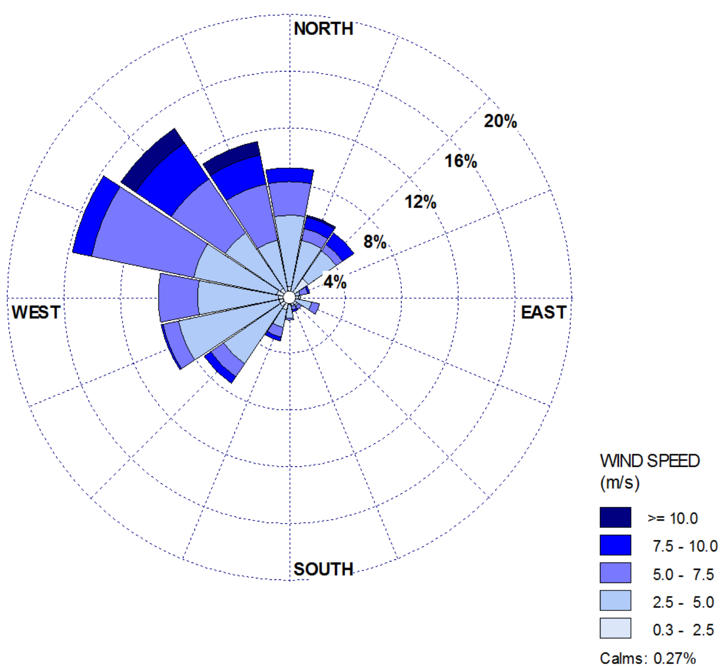

Figure 64 One-hour Wind Roses for the Month of January 2015 from the 50m level

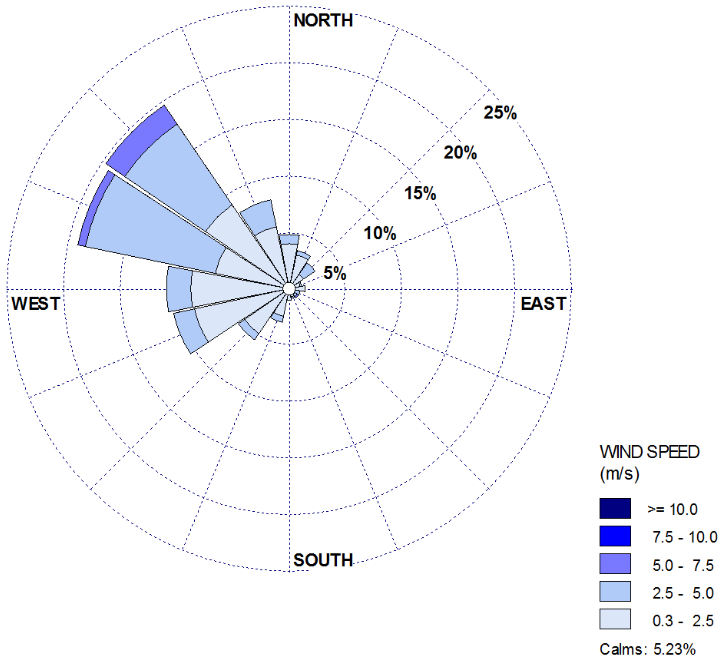

Figure 65 One-hour Wind Roses for the Month of January 2015 from the 10m level

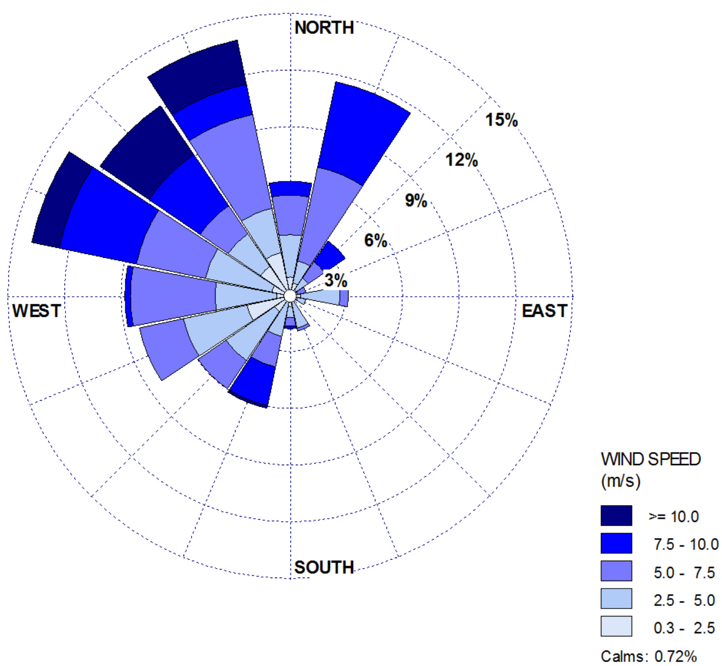

Figure 66 One-hour Wind Roses for the Month of February 2015 from the 85m level

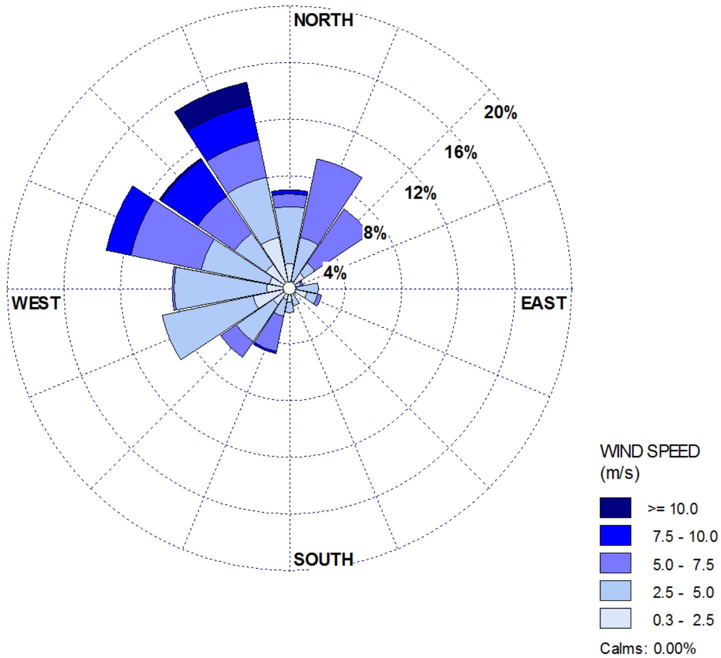

Figure 67 One-hour Wind Roses for the Month of February 2015 from the 50m level

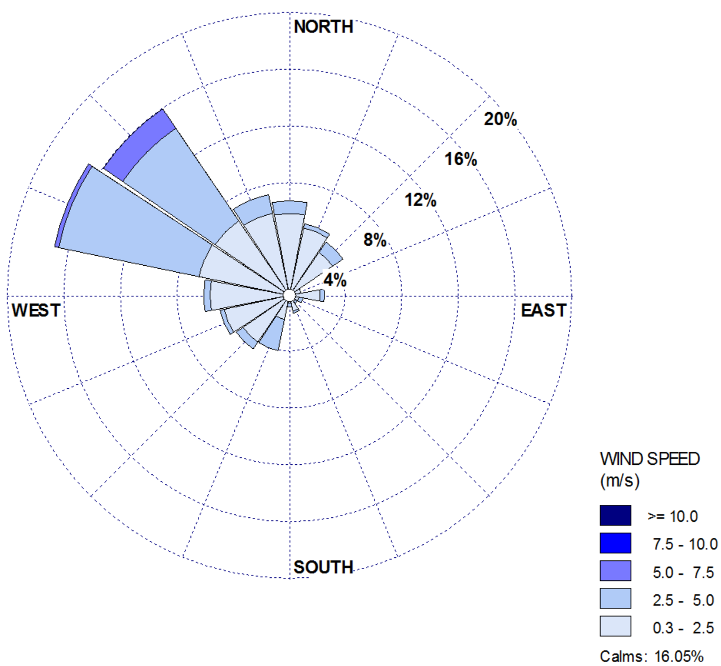

Figure 68 One-hour Wind Roses for the Month of February 2015 from the 10m level

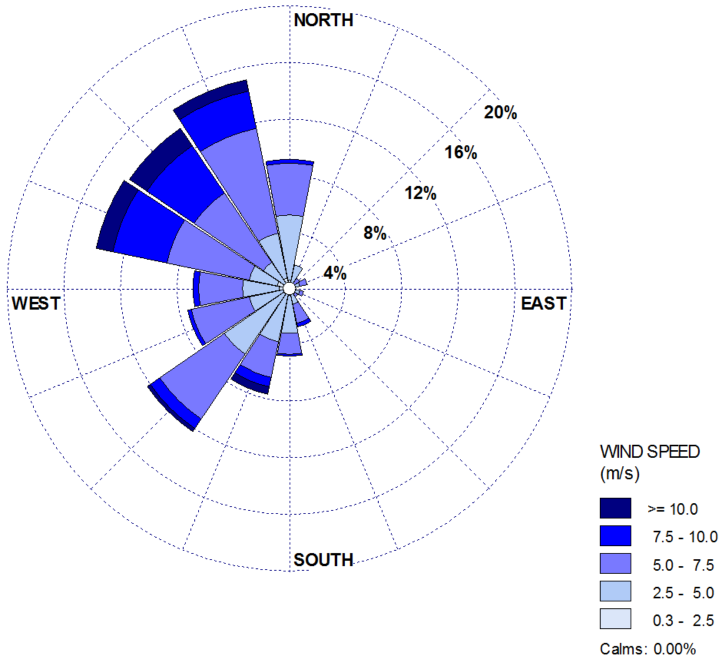

Figure 69 One-hour Wind Roses for the Month of March 2015 from the 85m level

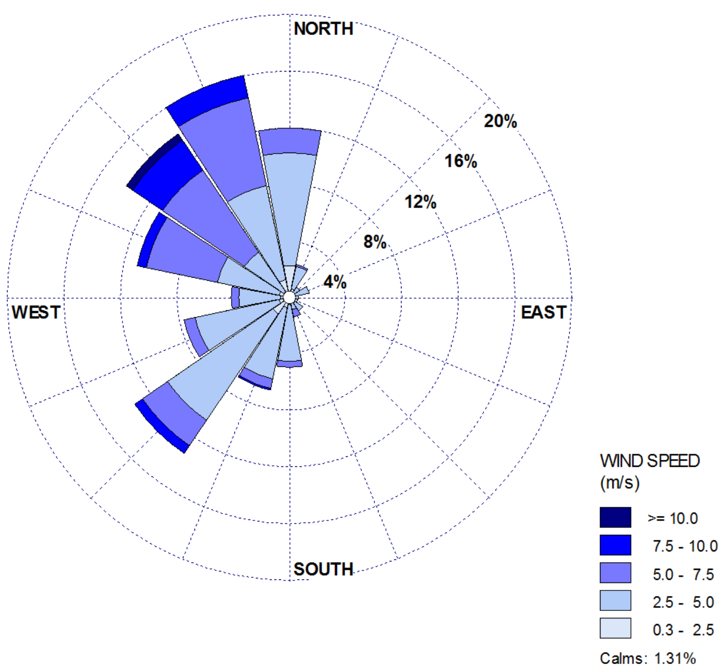

Figure 70 One-hour Wind Roses for the Month of March 2015 from the 50m level

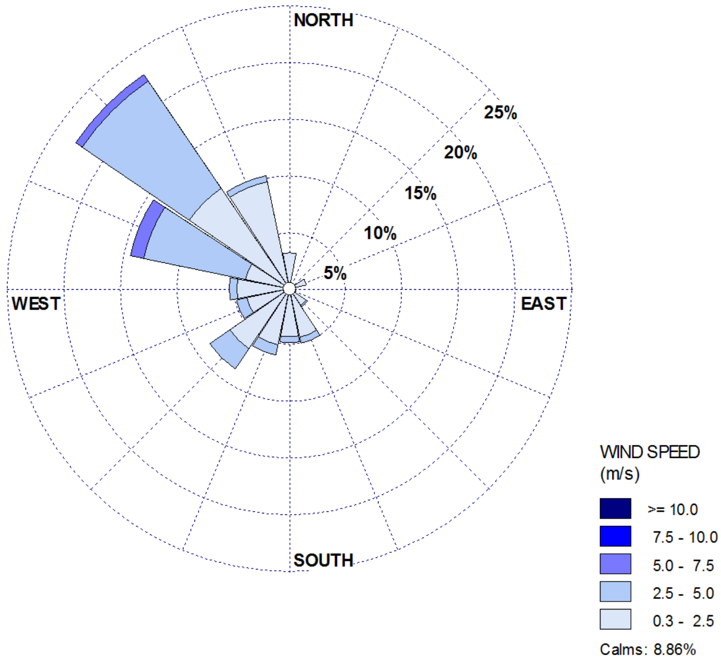

Figure 71 One-hour Wind Roses for the Month of March 2015 from the 10m level

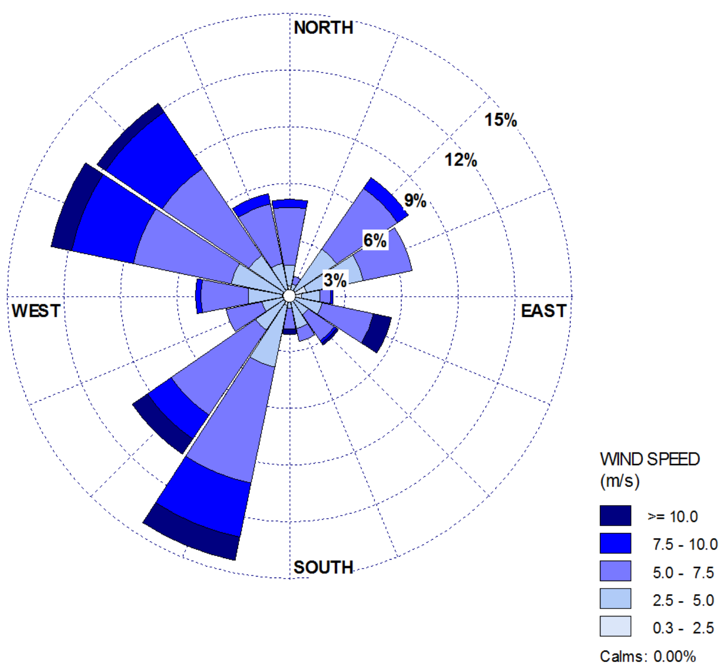

Figure 72 One-hour Wind Roses for the Month of April 2015 from the 85m level

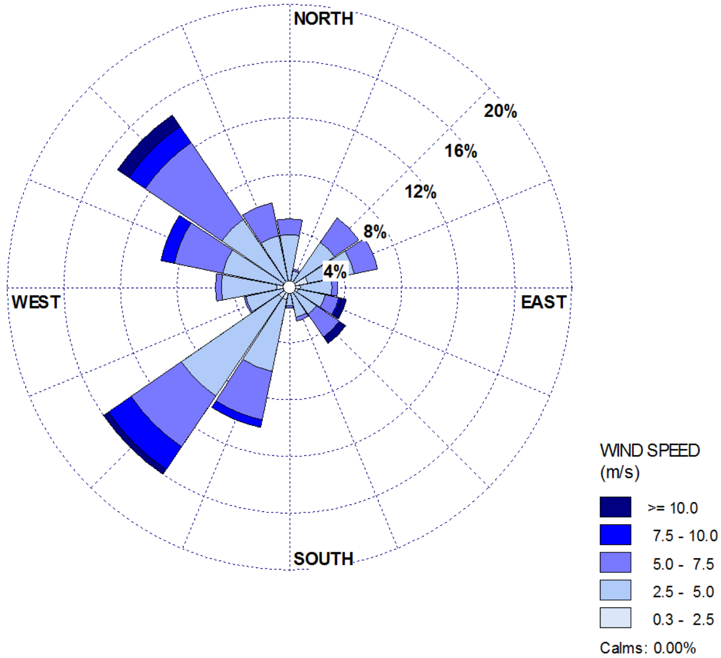

Figure 73 One-hour Wind Roses for the Month of April 2015 from the 50m level

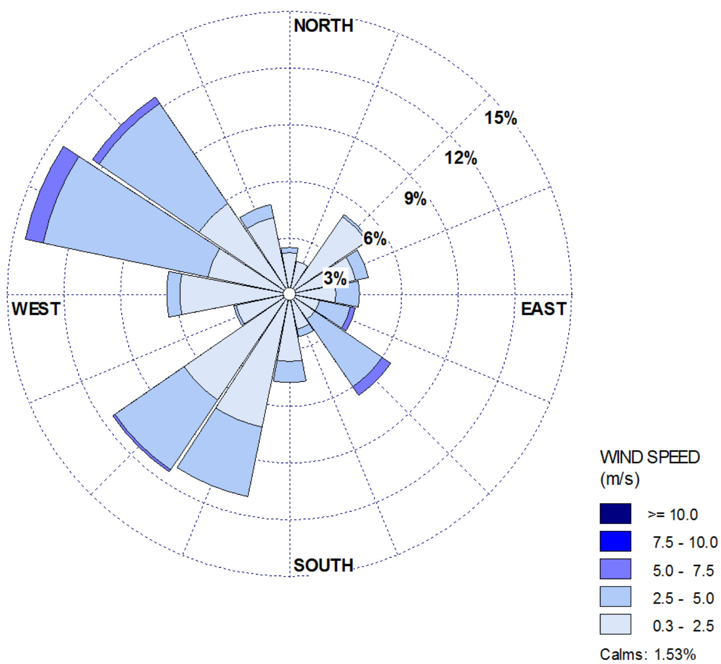

Figure 74 One-hour Wind Roses for the Month of April 2015 from the 10m level

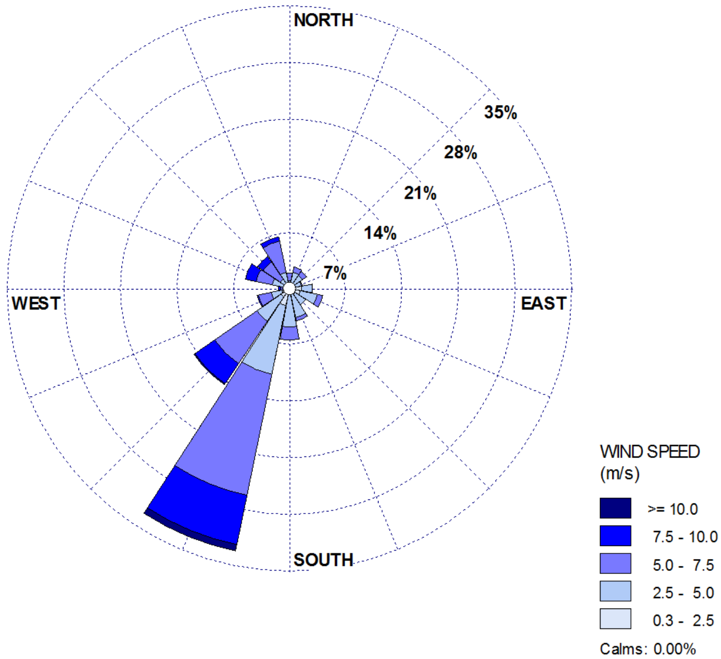

Figure 75 One-hour Wind Roses for the Month of May 2015 from the 85m level

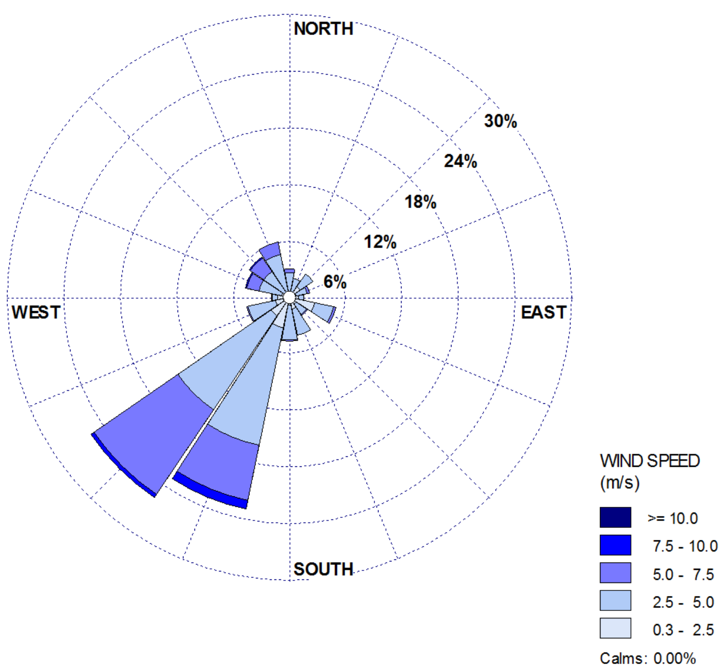

Figure 76 One-hour Wind Roses for the Month of May 2015 from the 50m level

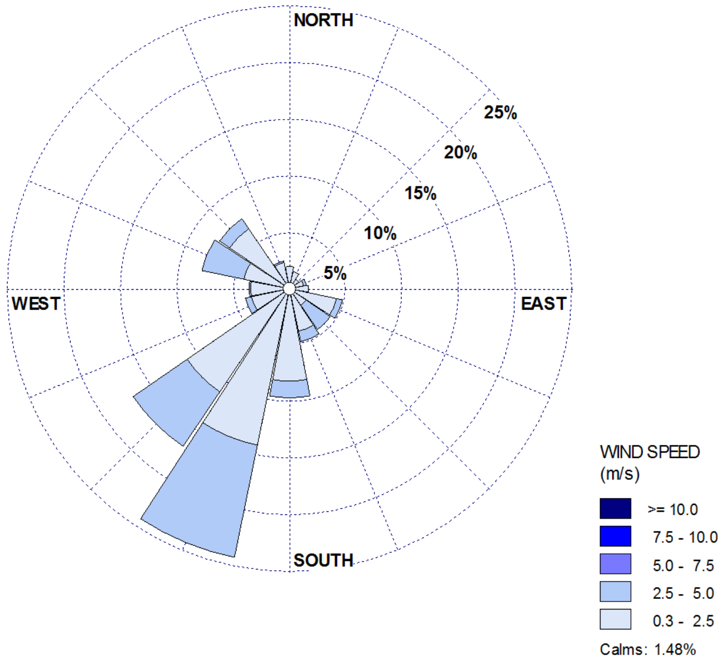

Figure 77 One-hour Wind Roses for the Month of May 2015 from the 10m level

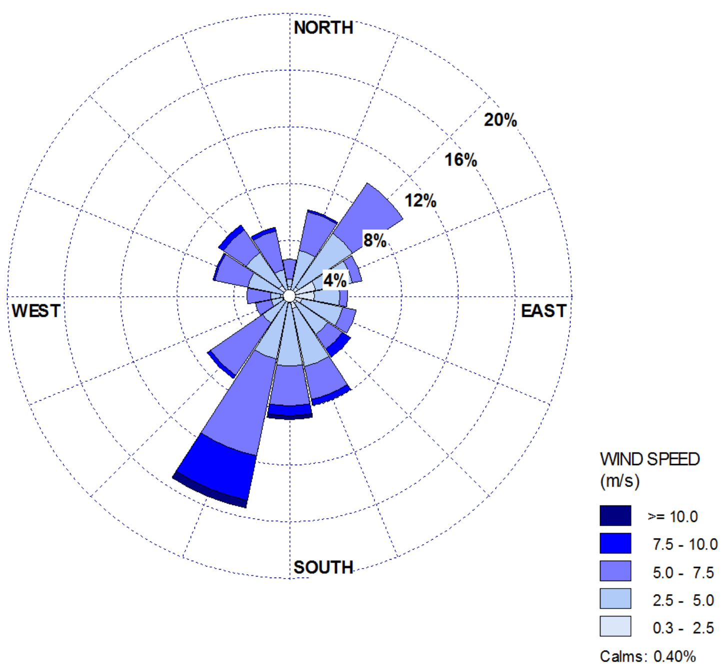

Figure 78 One-hour Wind Roses for the Month of June 2015 from the 85m level

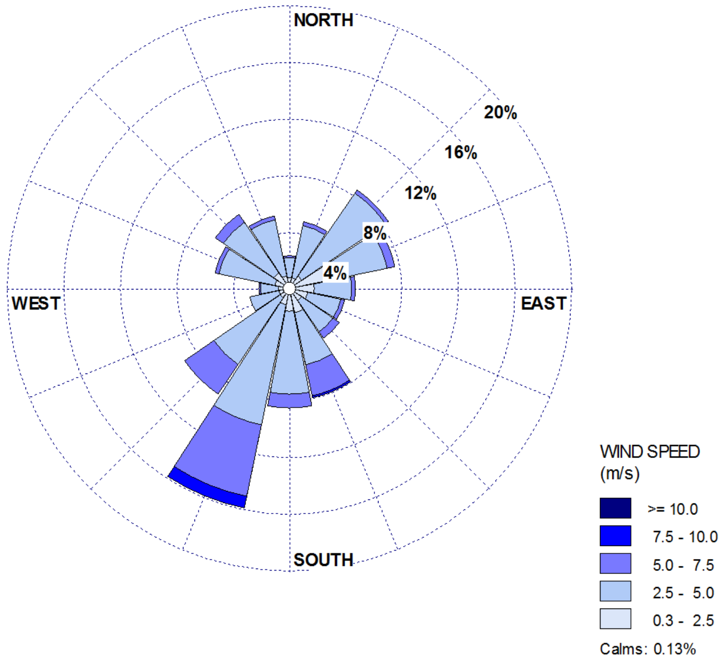

Figure 79 One-hour Wind Roses for the Month of June 2015 from the 50m level

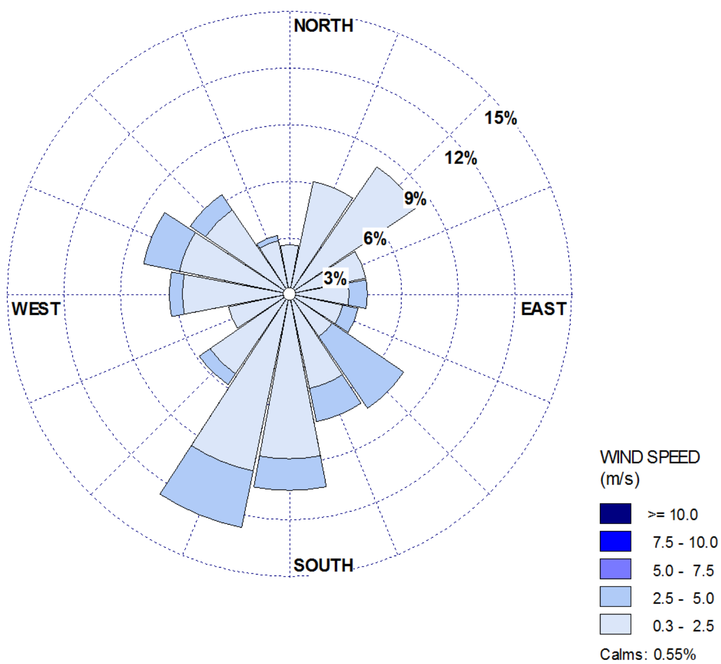

Figure 80 One-hour Wind Roses for the Month of June 2015 from the 10m level

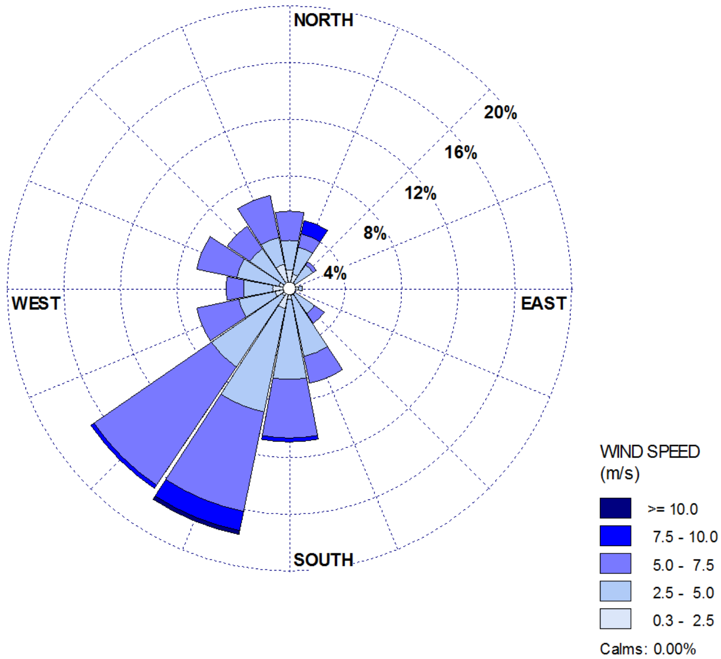

Figure 81 One-hour Wind Roses for the Month of July 2015 from the 85m level

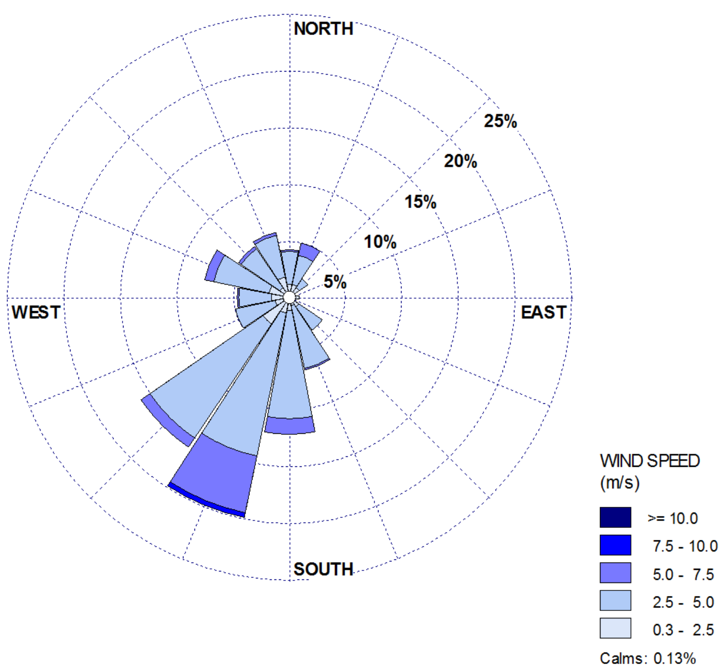

Figure 82 One-hour Wind Roses for the Month of July 2015 from the 50m level

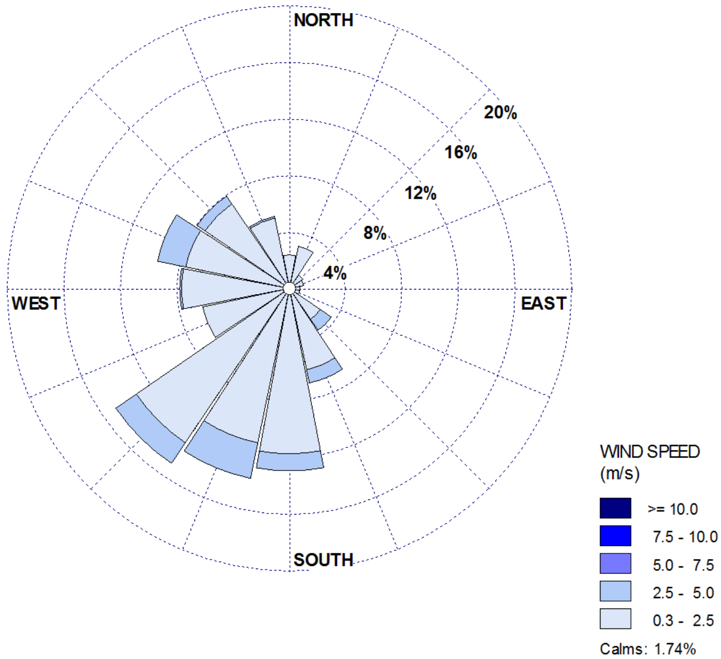

Figure 83 One-hour Wind Roses for the Month of July 2015 from the 10m level

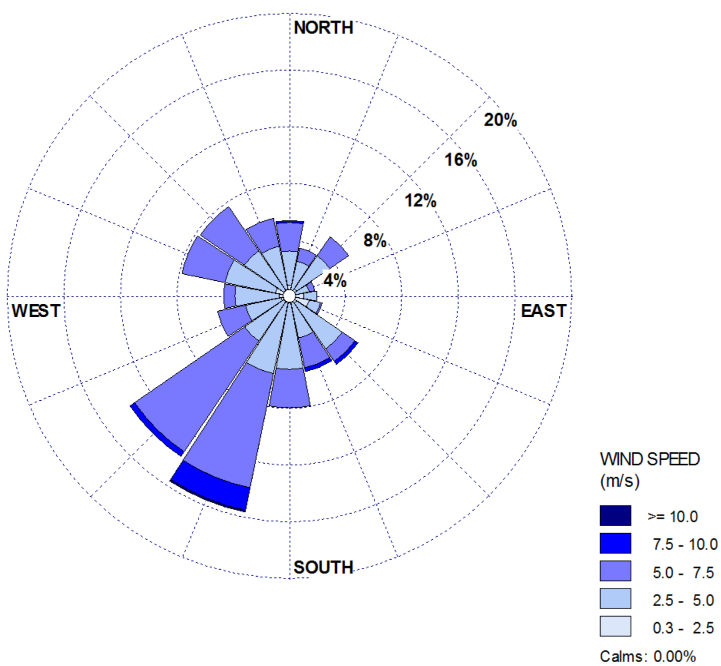

Figure 84 One-hour Wind Roses for the Month of August 2015 from the 85m level

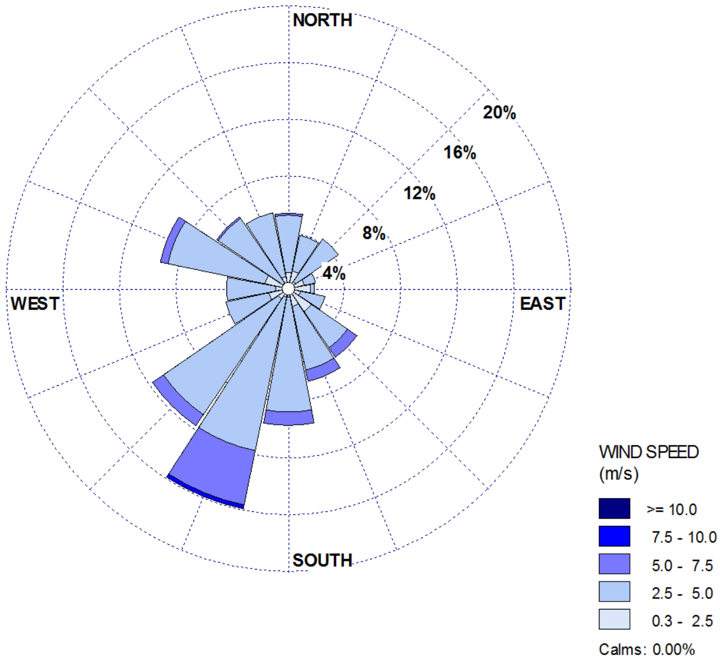

Figure 85 One-hour Wind Roses for the Month of August 2015 from the 50m level

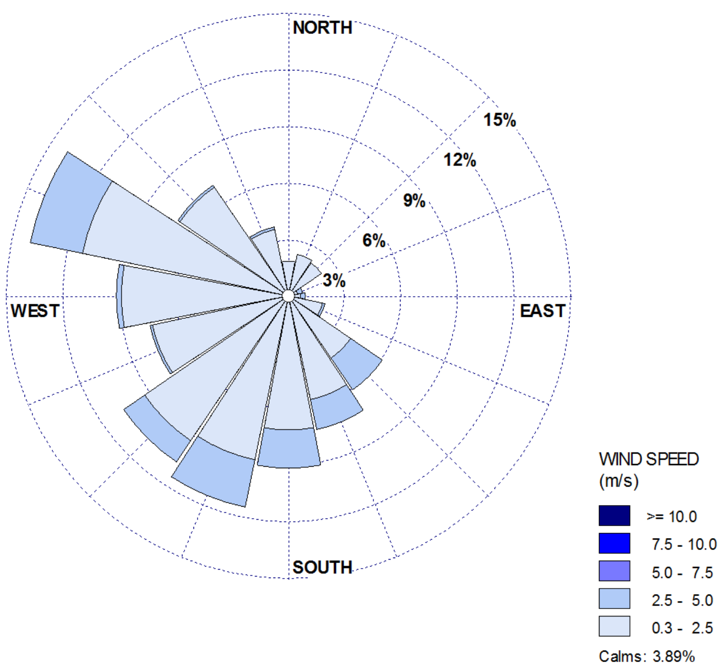

Figure 86 One-hour Wind Roses for the Month of August 2015 from the 10m level

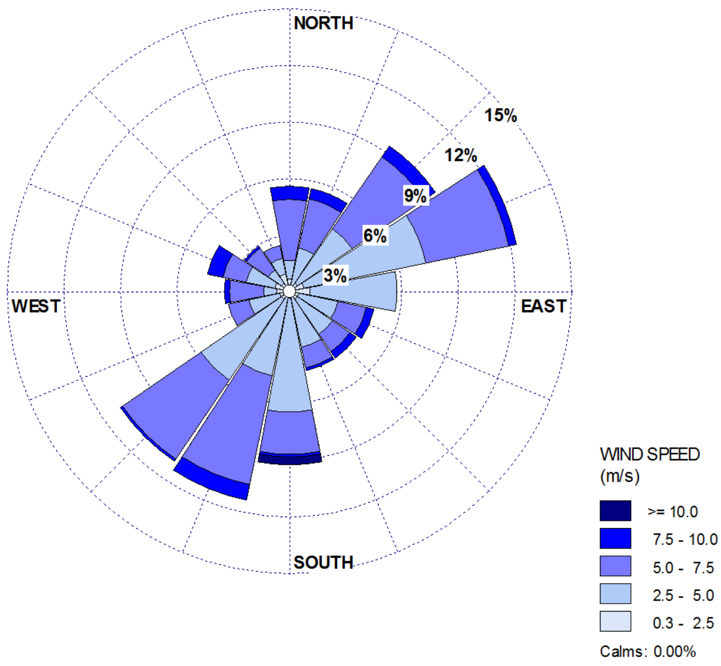

Figure 87 One-hour Wind Roses for the Month of September 2015 from the 85m level

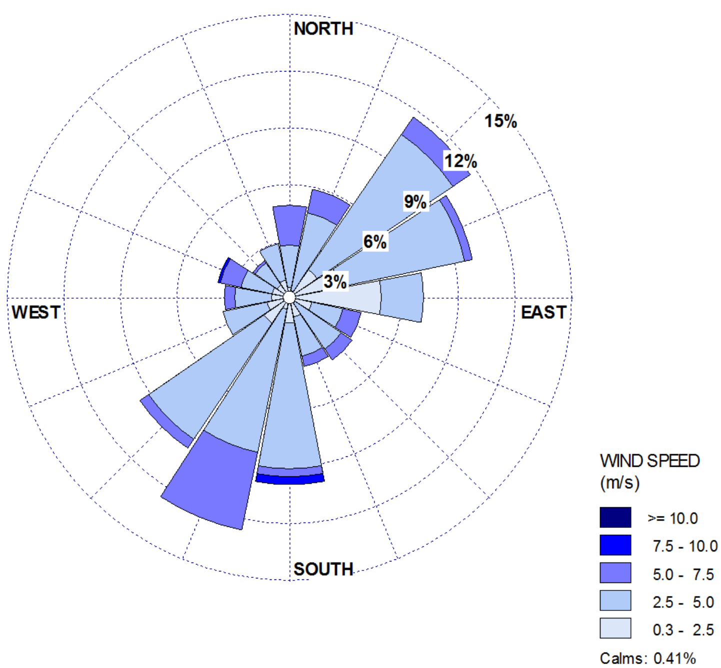

Figure 88 One-hour Wind Roses for the Month of September 2015 from the 50m level

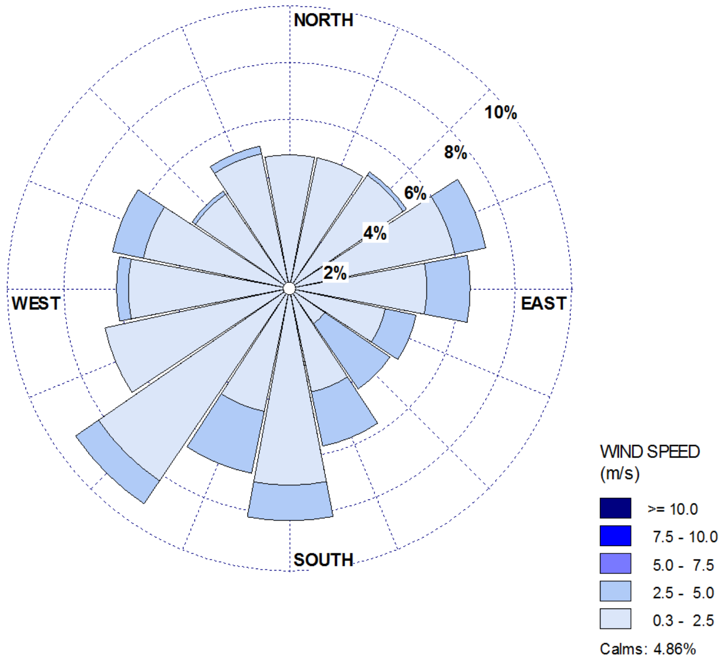

Figure 89 One-hour Wind Roses for the Month of September 2015 from the 10m level

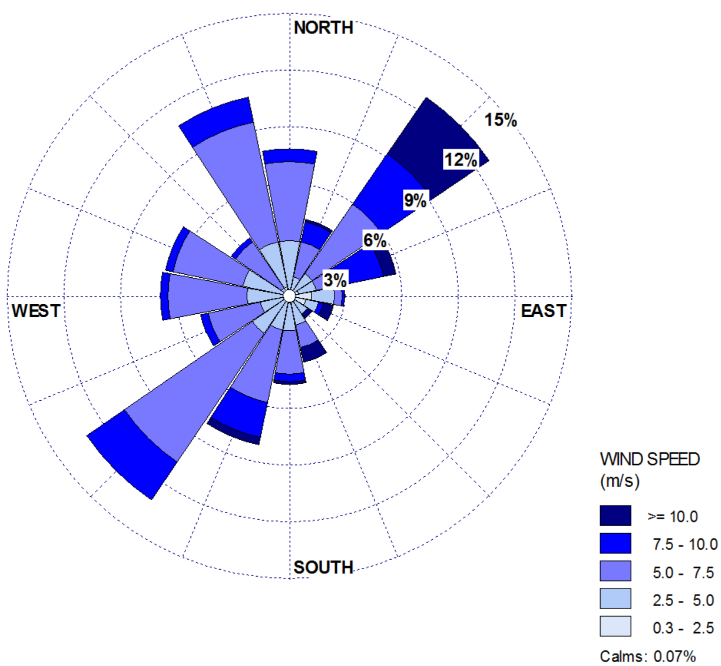

Figure 90 One-hour Wind Roses for the Month of October 2015 from the 85m level

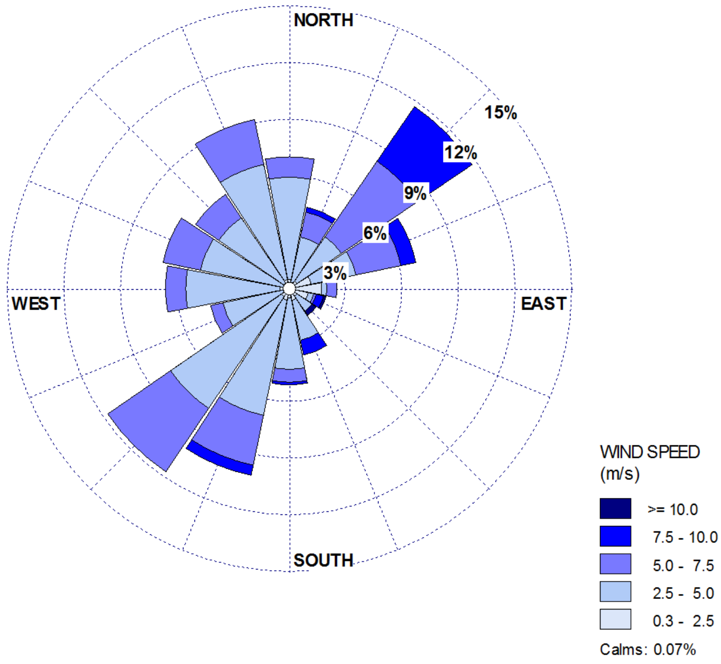

Figure 91 One-hour Wind Roses for the Month of October 2015 from the 50m level

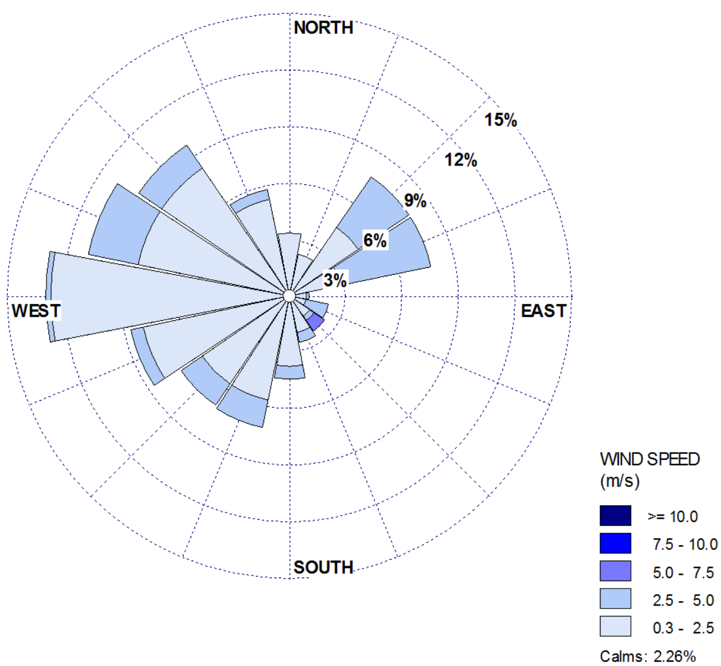

Figure 92 One-hour Wind Roses for the Month of October 2015 from the 10m level

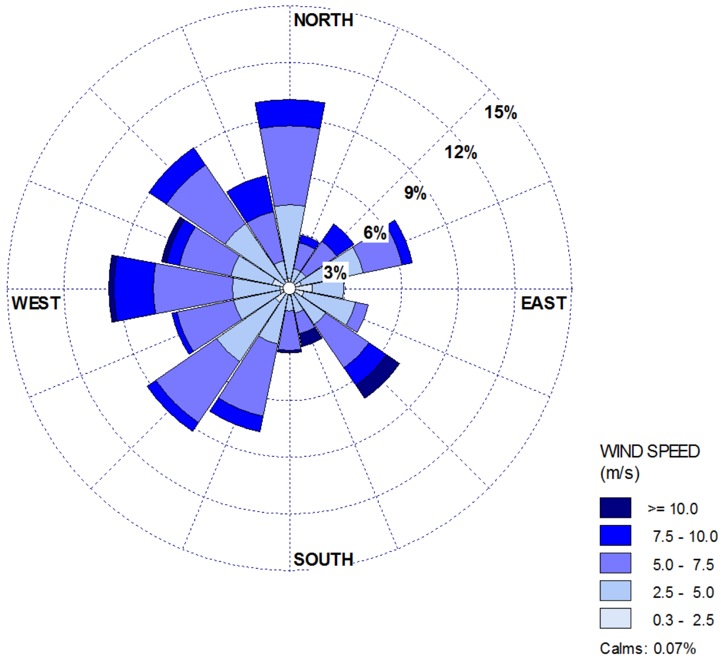

Figure 93 One-hour Wind Roses for the Month of November 2015 from the 85m level

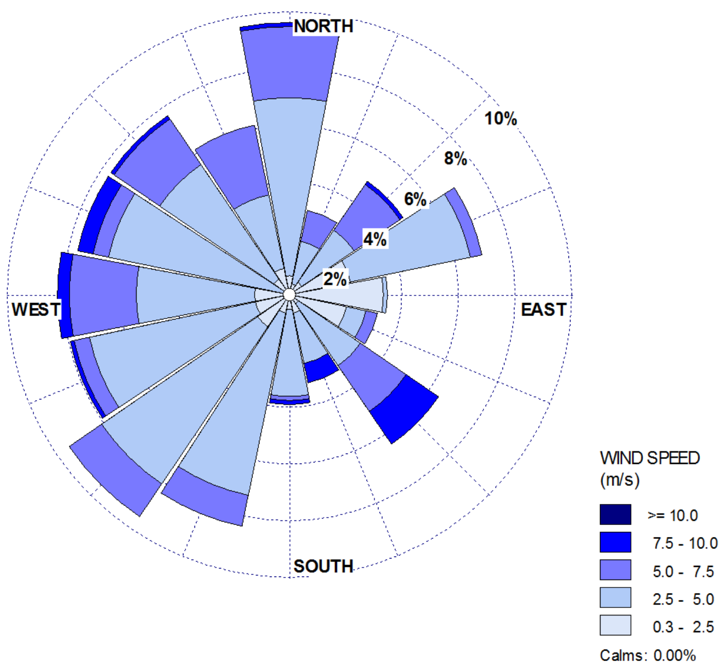

Figure 94 One-hour Wind Roses for the Month of November 2015 from the 50m level

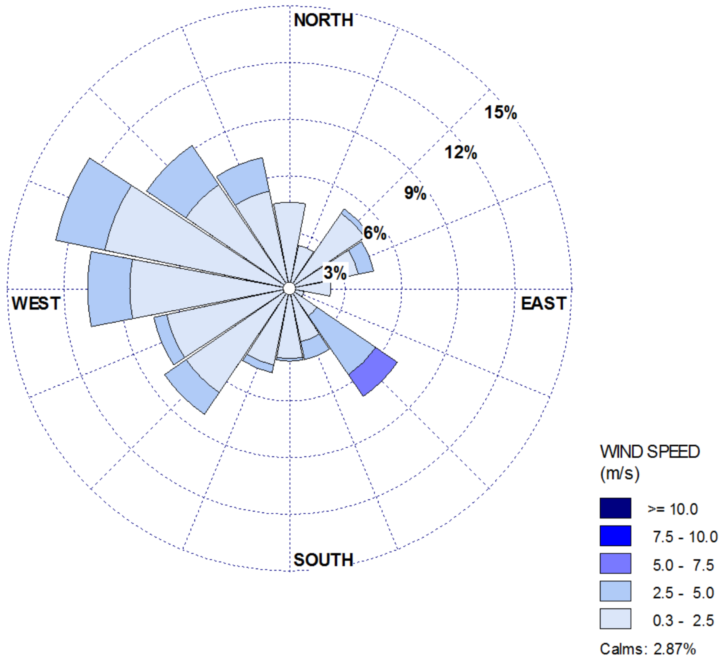

Figure 95 One-hour Wind Roses for the Month of November 2015 from the 10m level

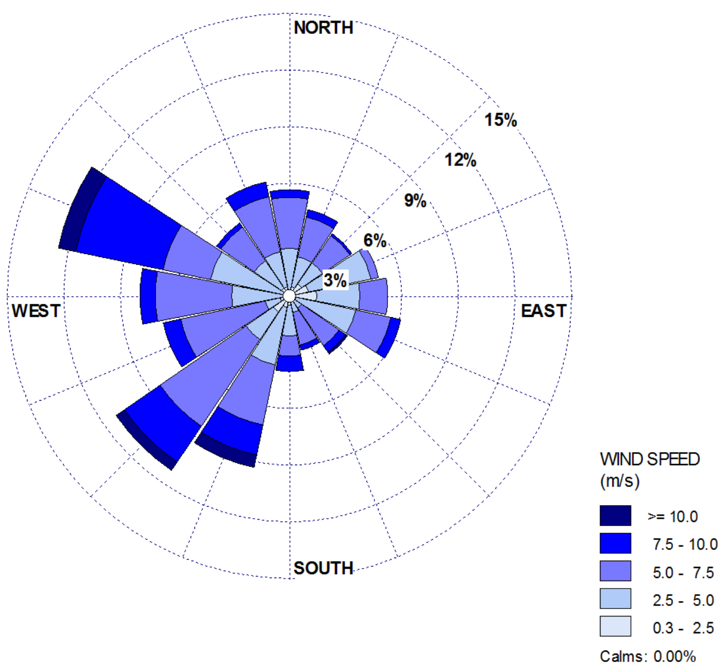

Figure 96 One-hour Wind Roses for the Month of December 2015 from the 85m level

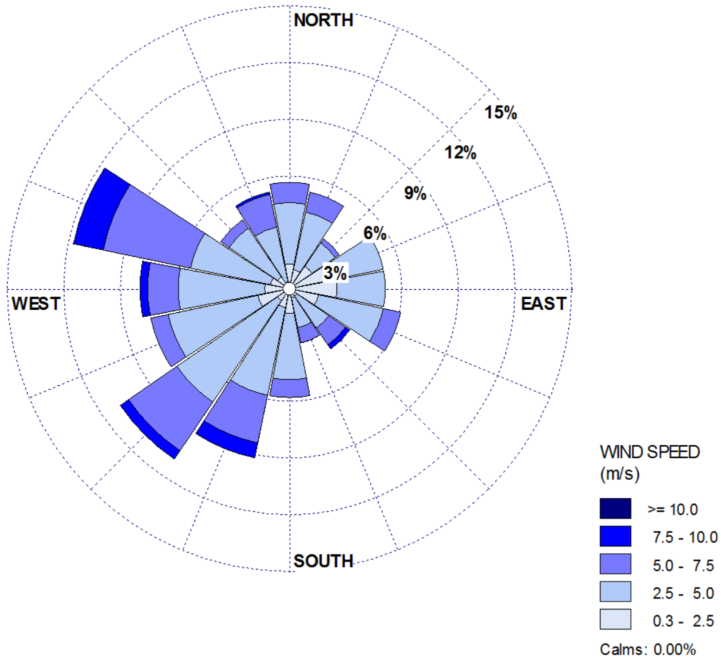

Figure 97 One-hour Wind Roses for the Month of December 2015 from the 50m level

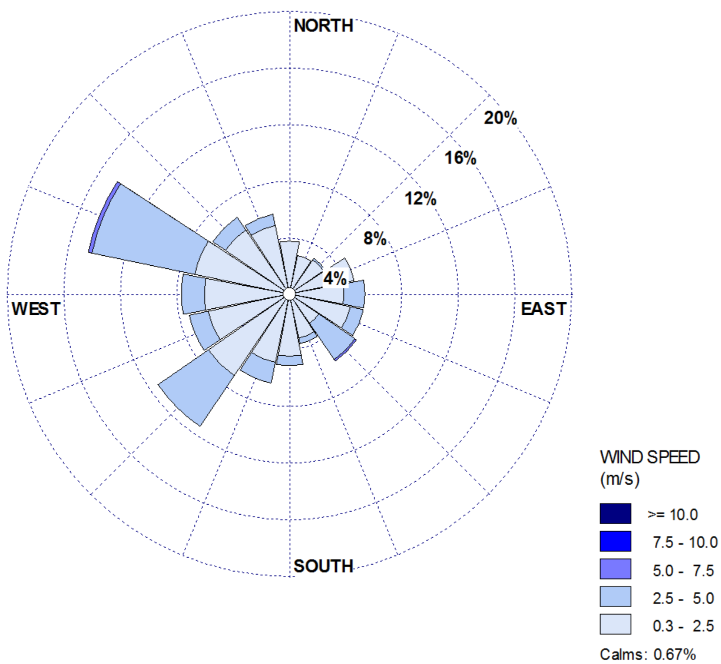

Figure 98 One-hour Wind Roses for the Month of December 2015 from the 10m level

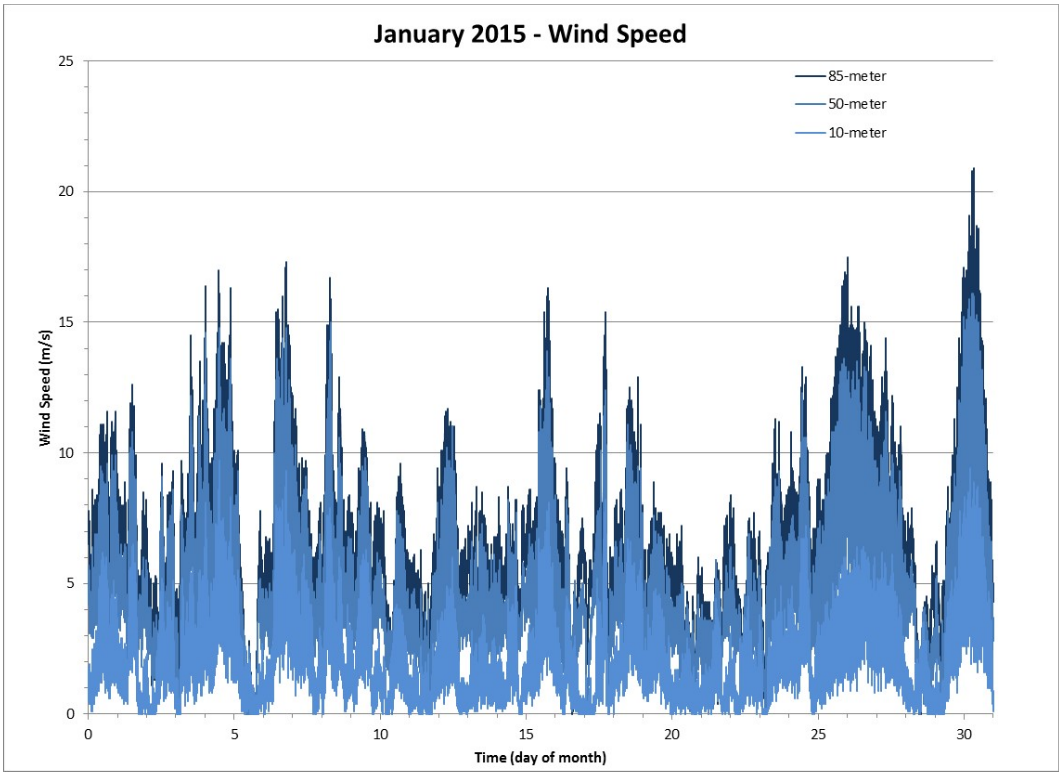

Figure 99 Wind Speed for the Month of January 2015

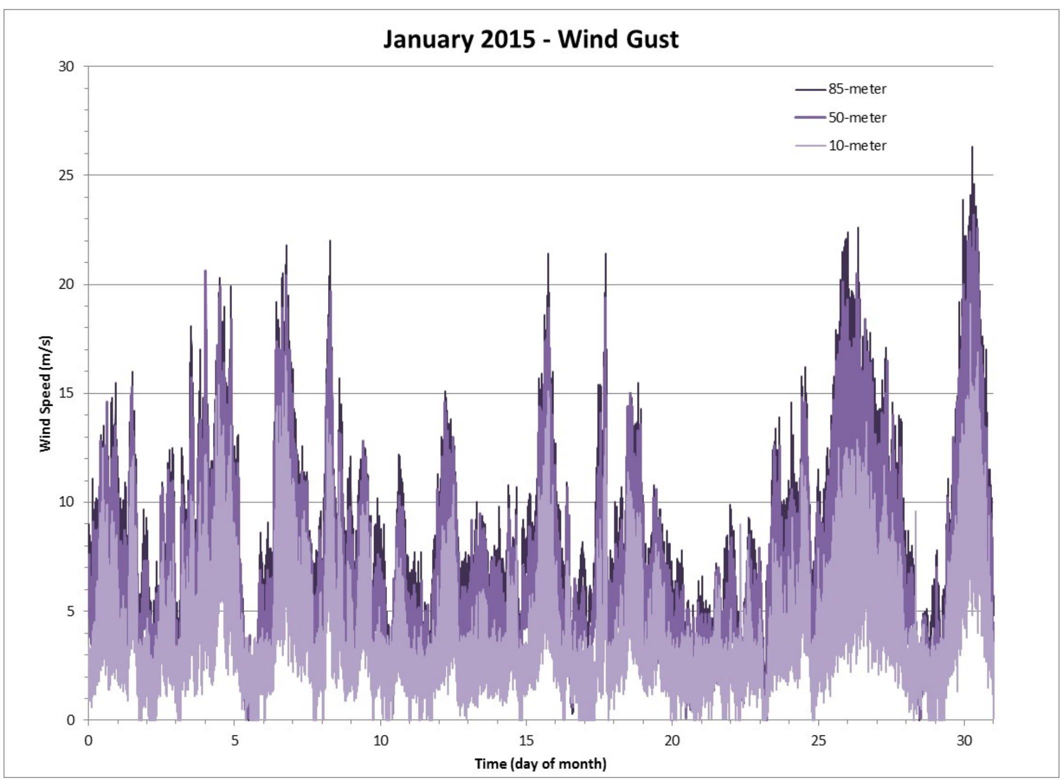

Figure 100 Wind Gust data for the Month of January 2015

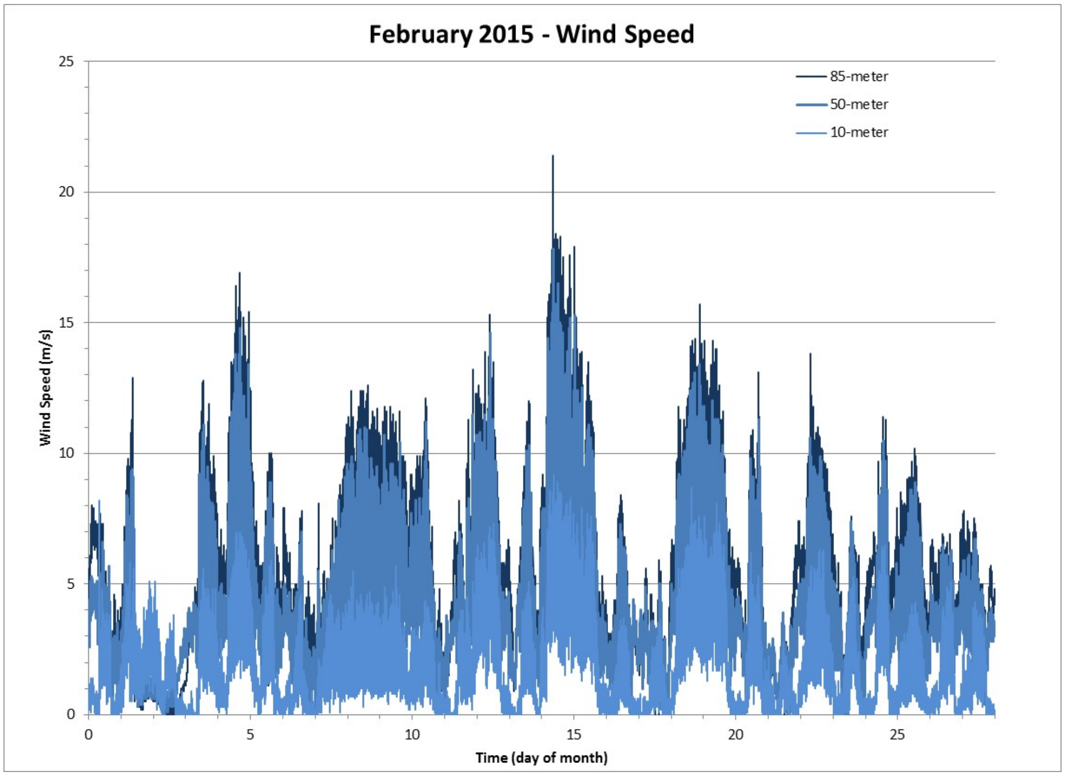

Figure 101 Wind Speed for the Month of February 2015

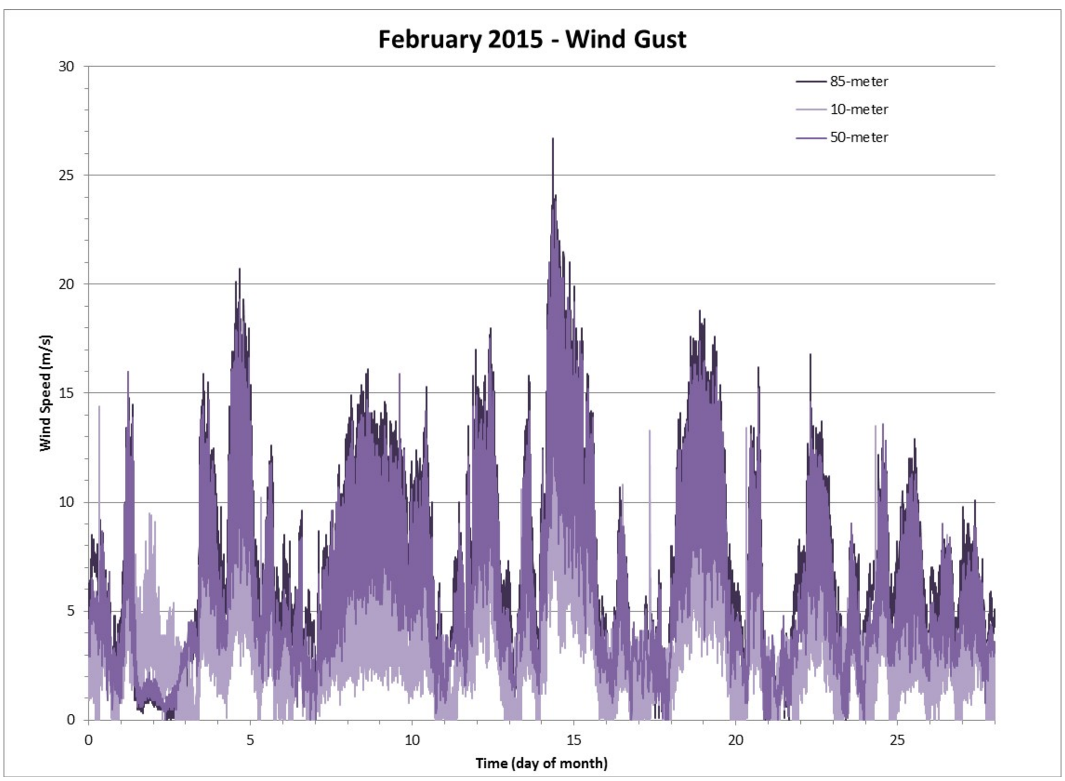

Figure 102 Wind Gust data for the Month of February 2015

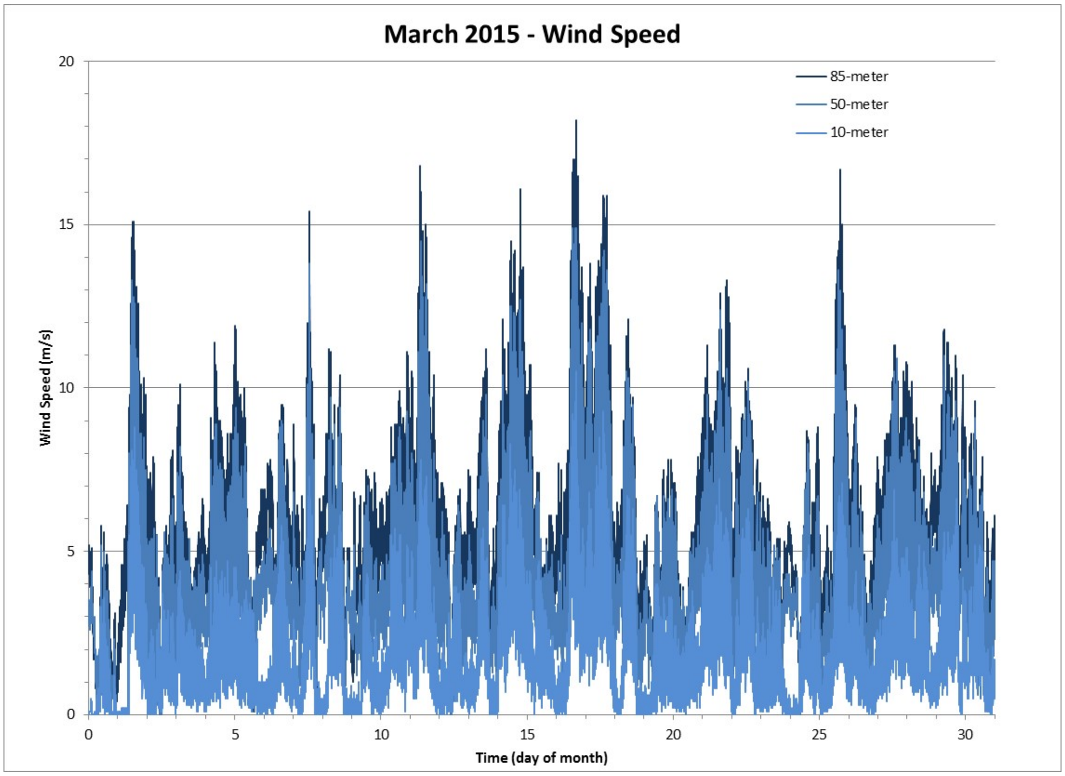

Figure 103 Wind Speed for the Month of March 2015

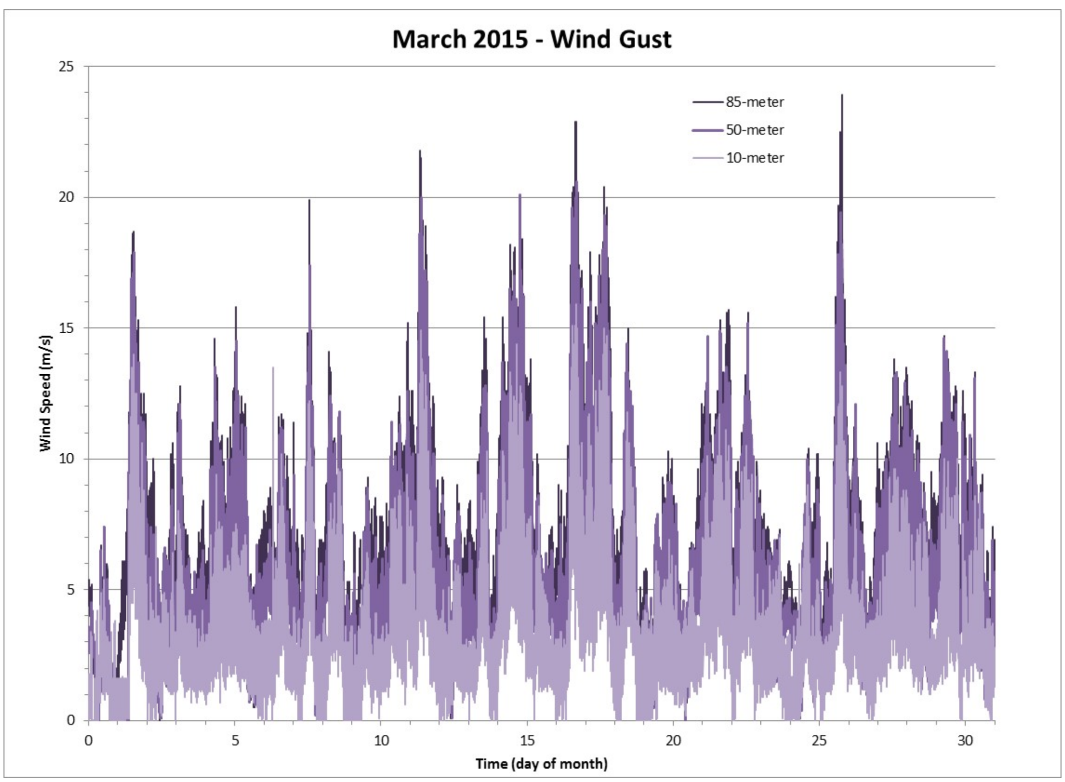

Figure 104 Wind Gust data for the Month of March 2015

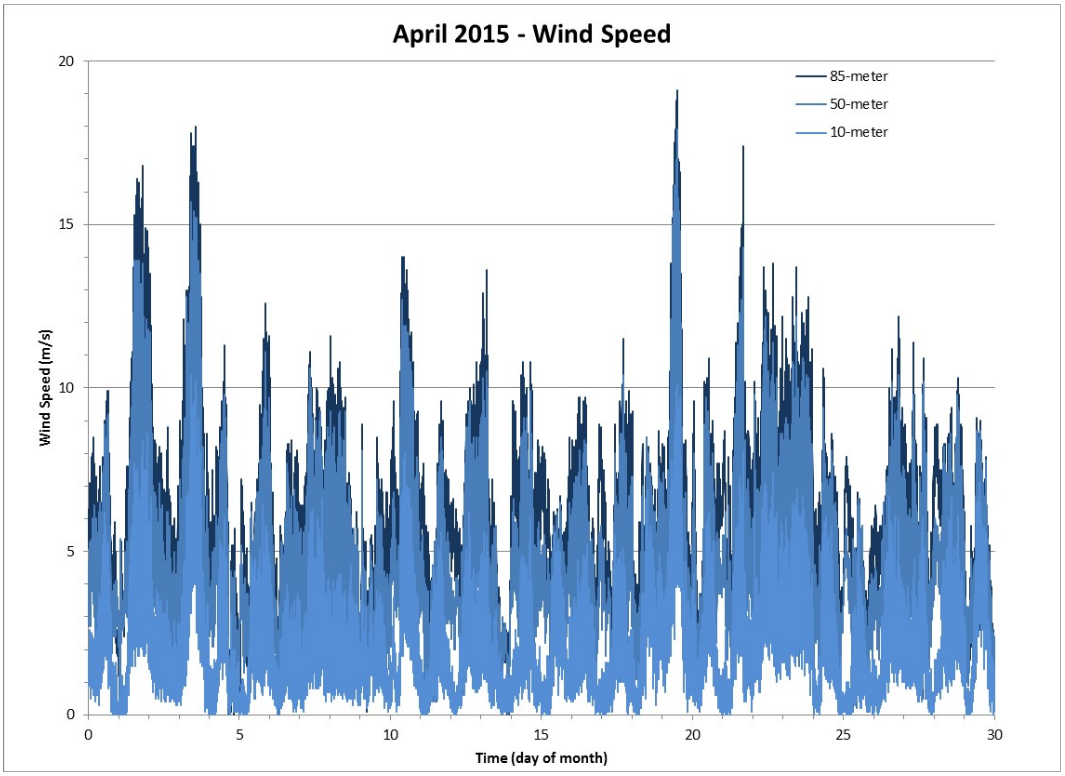

Figure 105 Wind Speed for the Month of April 2015

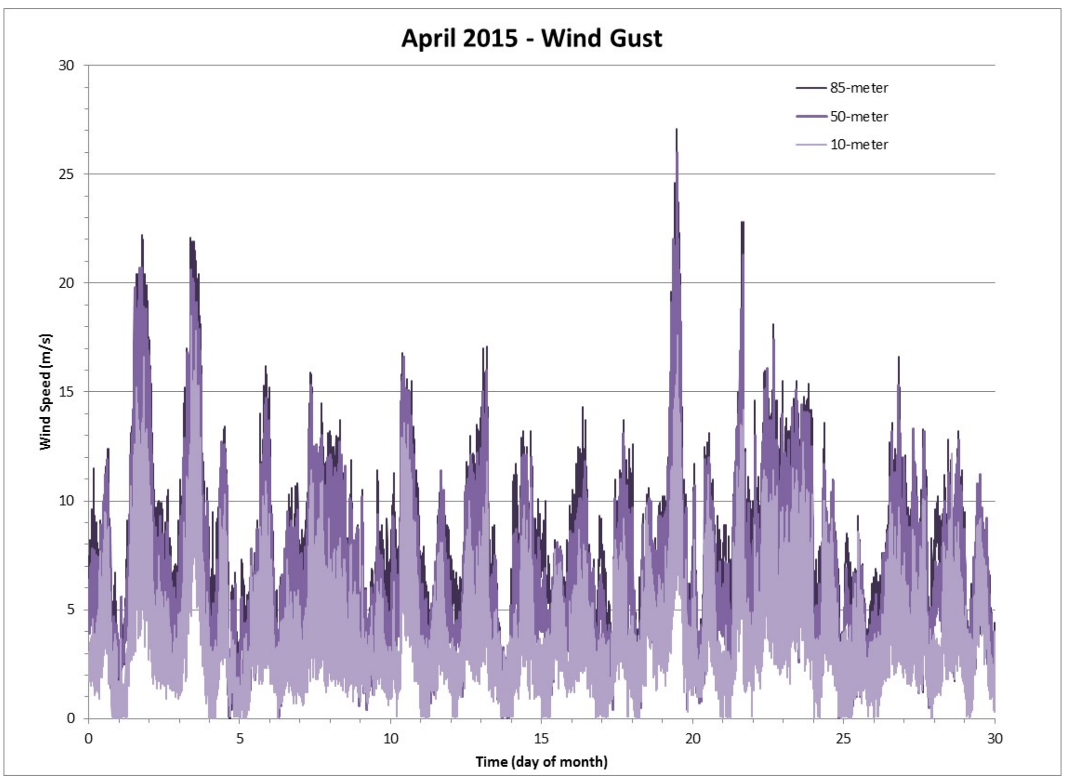

Figure 106 Wind Gust data for the Month of April 2015

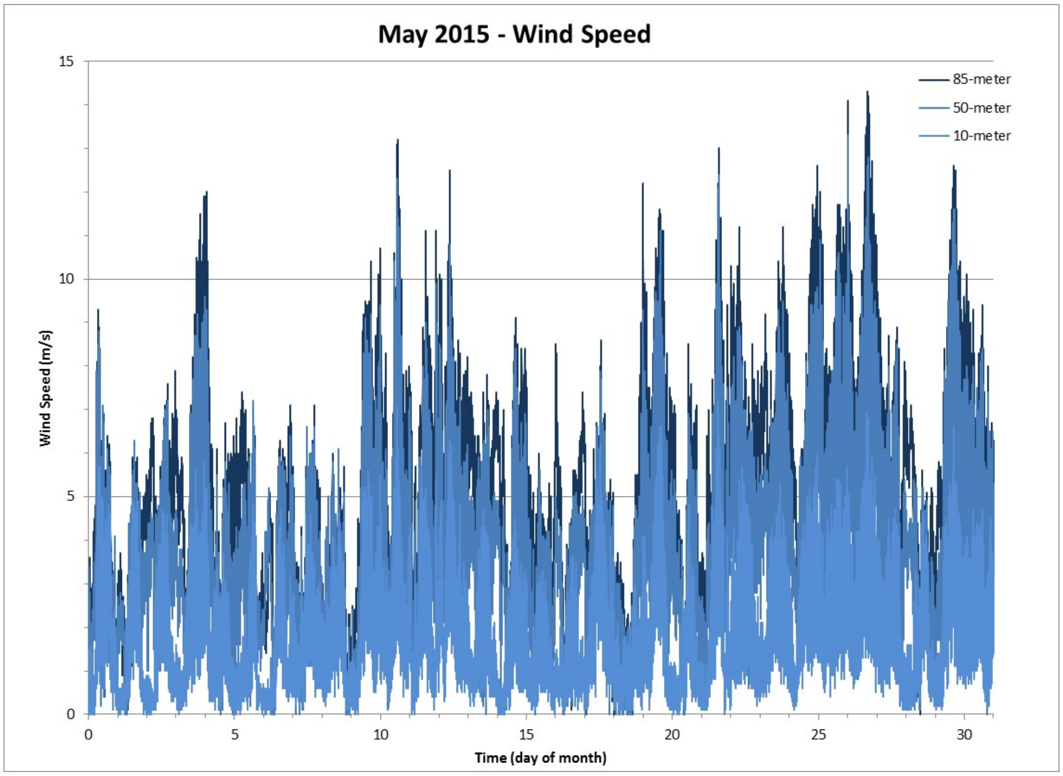

Figure 107 Wind Speed for the Month of May 2015

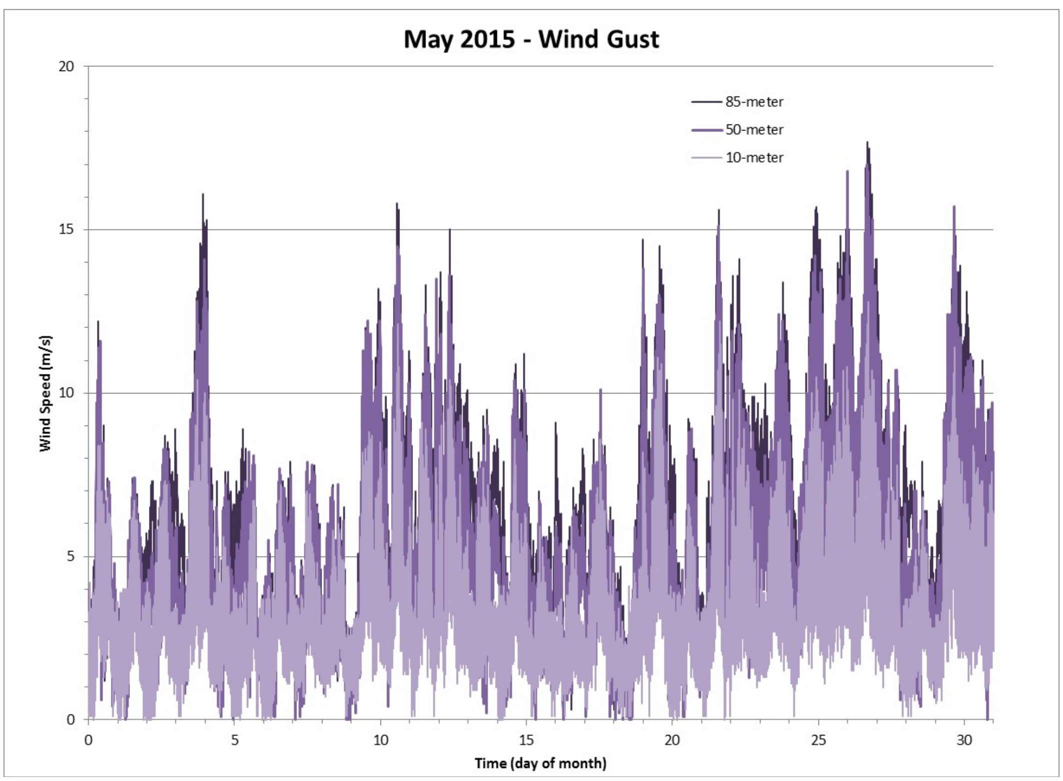

Figure 108 Wind Gust data for the Month of May 2015

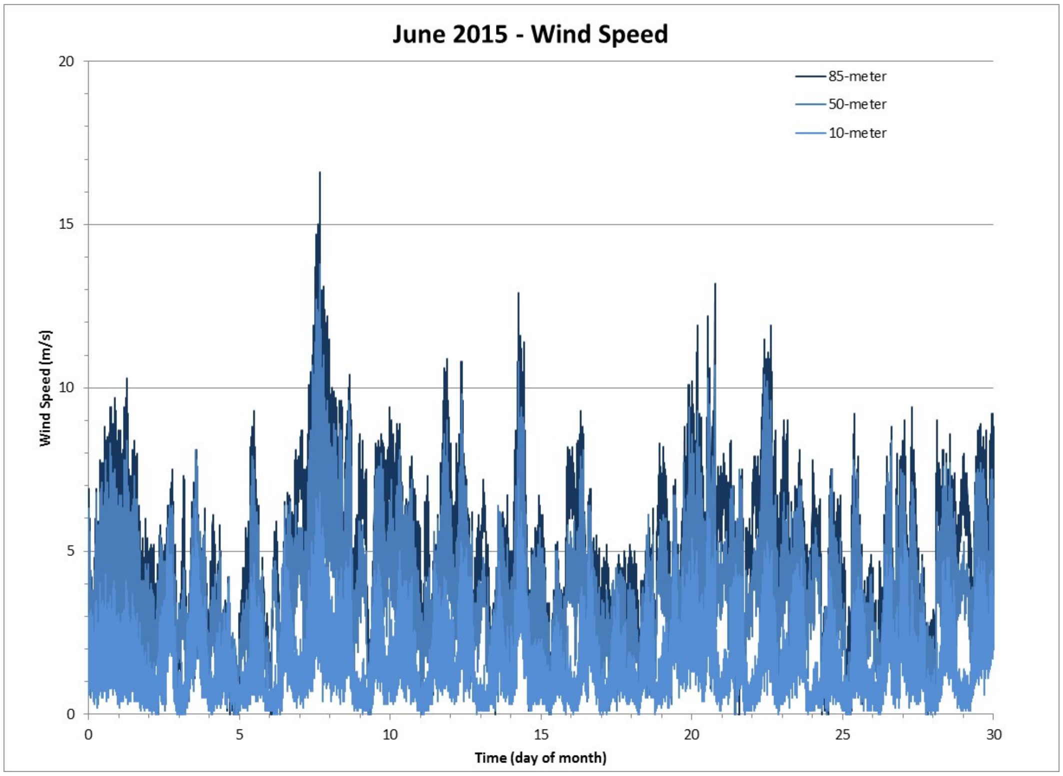

Figure 109 Wind Speed for the Month of June 2015

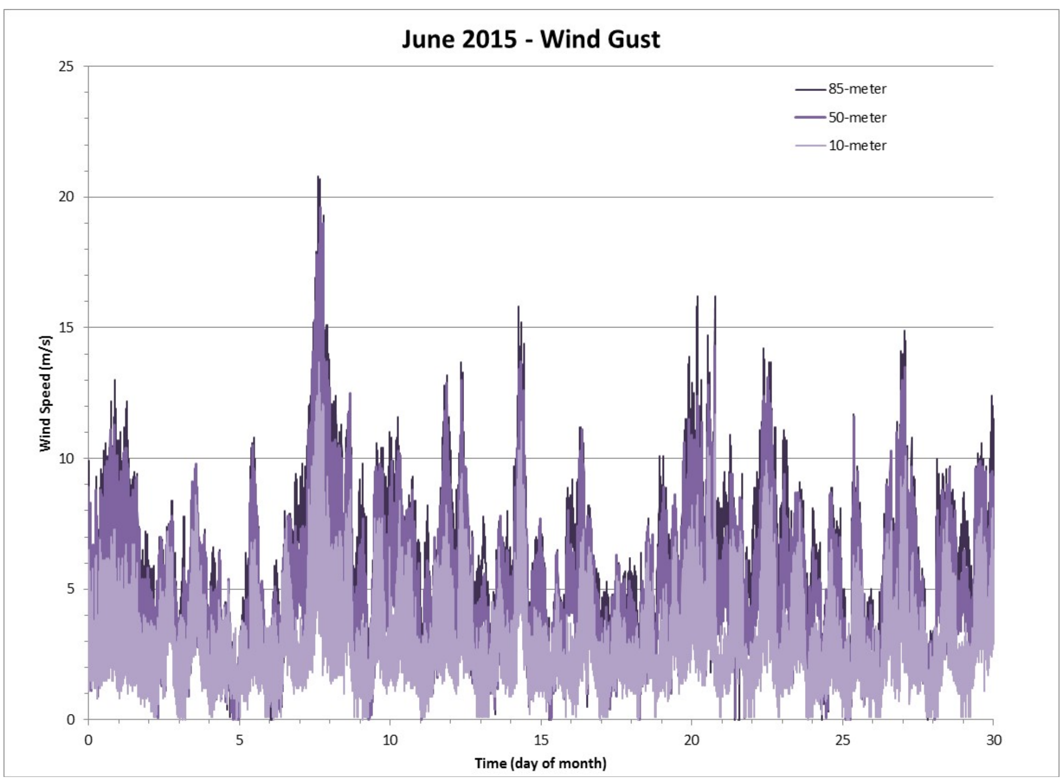

Figure 110 Wind Gust data for the Month of June 2015

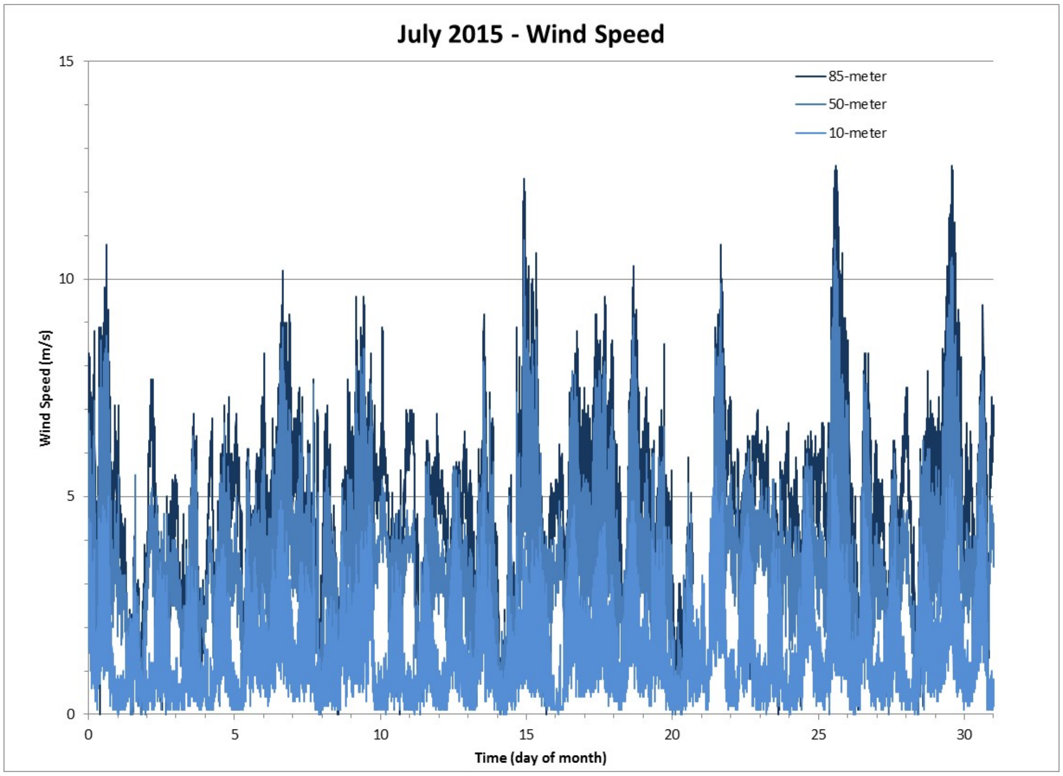

Figure 111 Wind Speed for the Month of July 2015

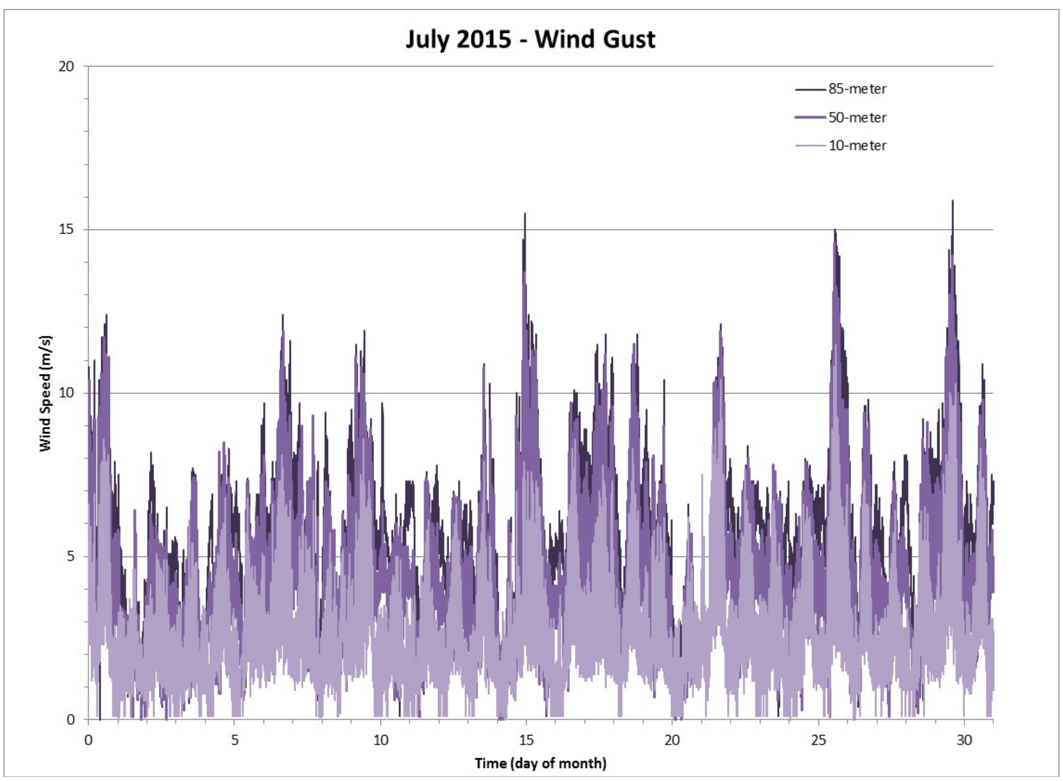

Figure 112 Wind Gust data for the Month of July 2015

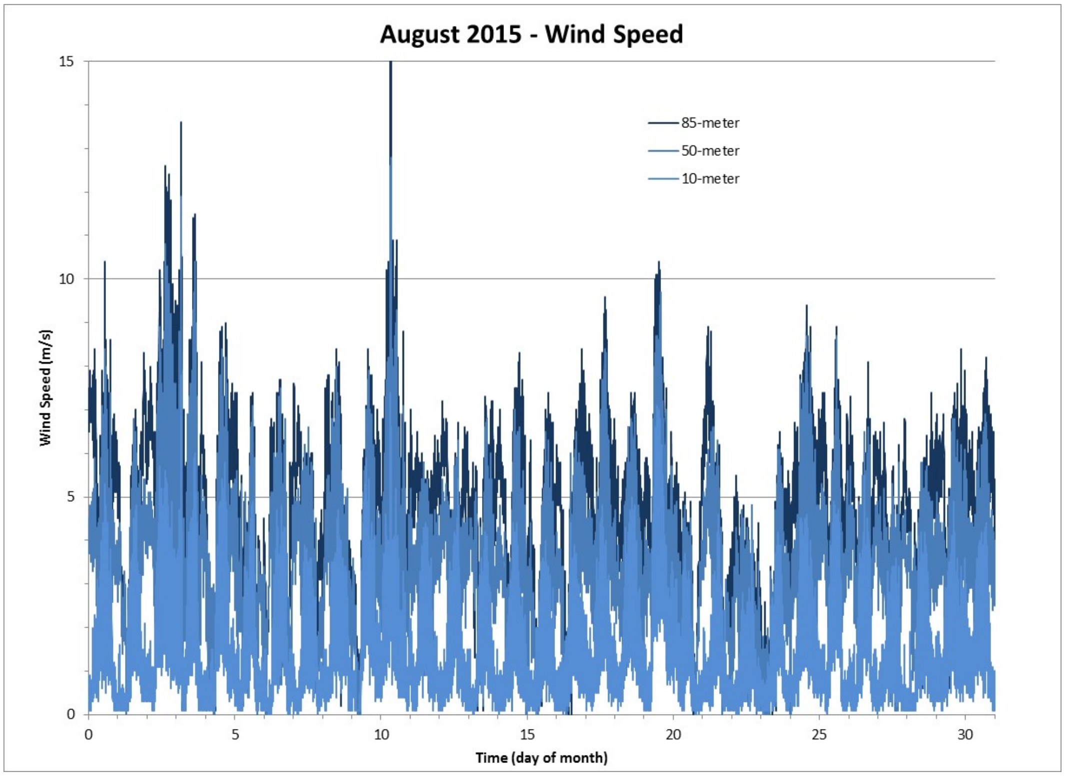

Figure 113 Wind Speed for the Month of August 2015

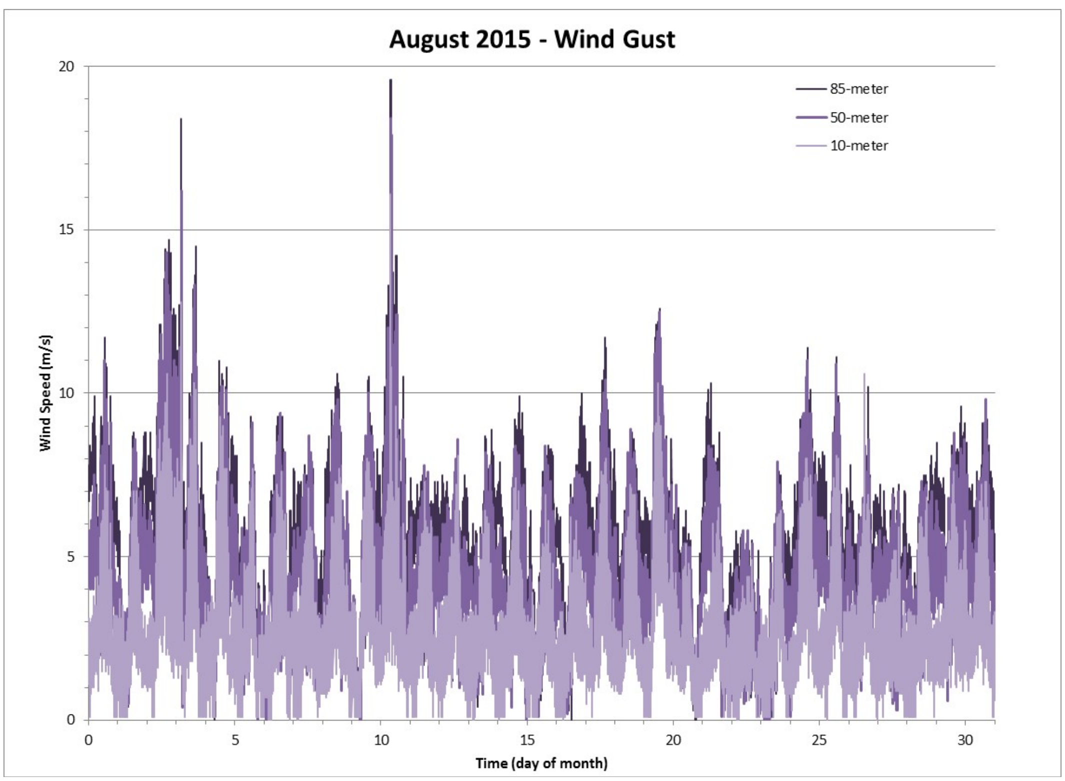

Figure 114 Wind Gust data for the Month of August 2015

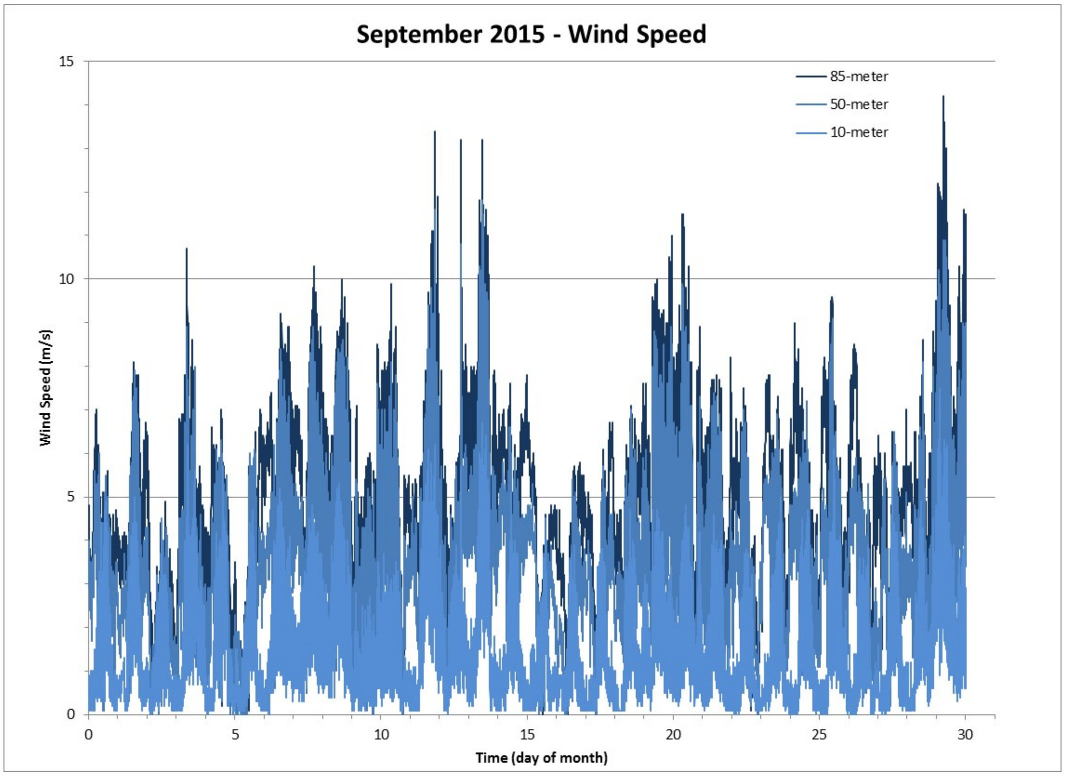

Figure 115 Wind Speed for the Month of September 2015

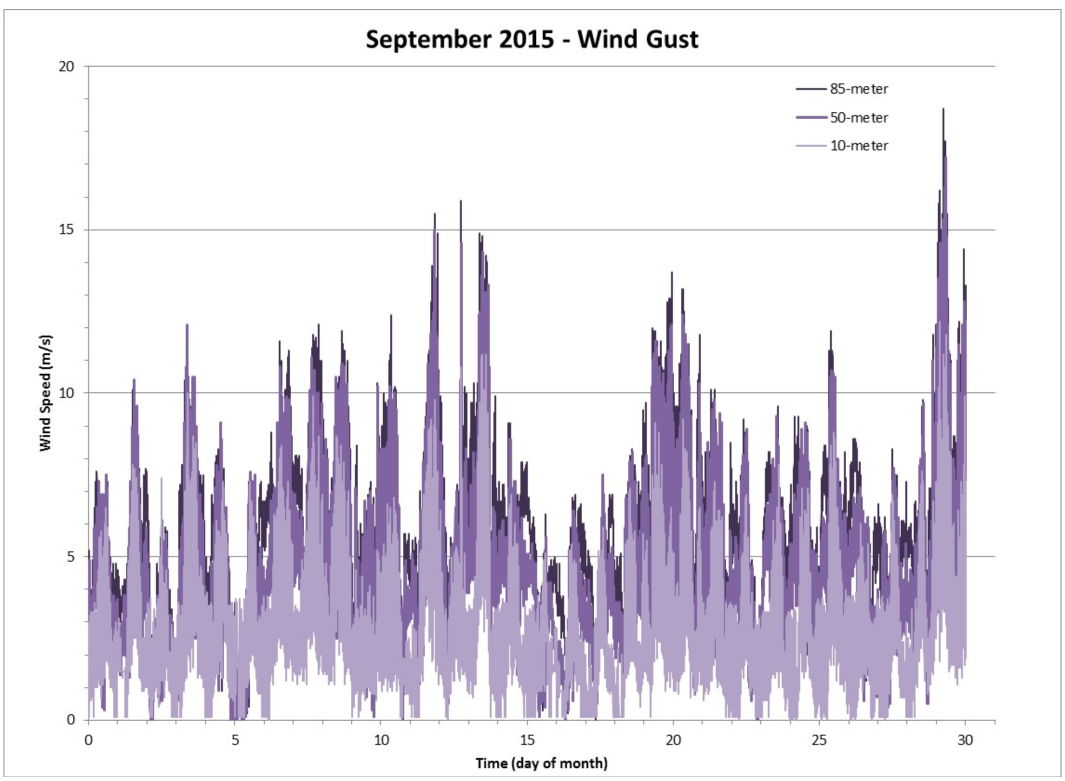

Figure 116 Wind Gust data for the Month of September 2015

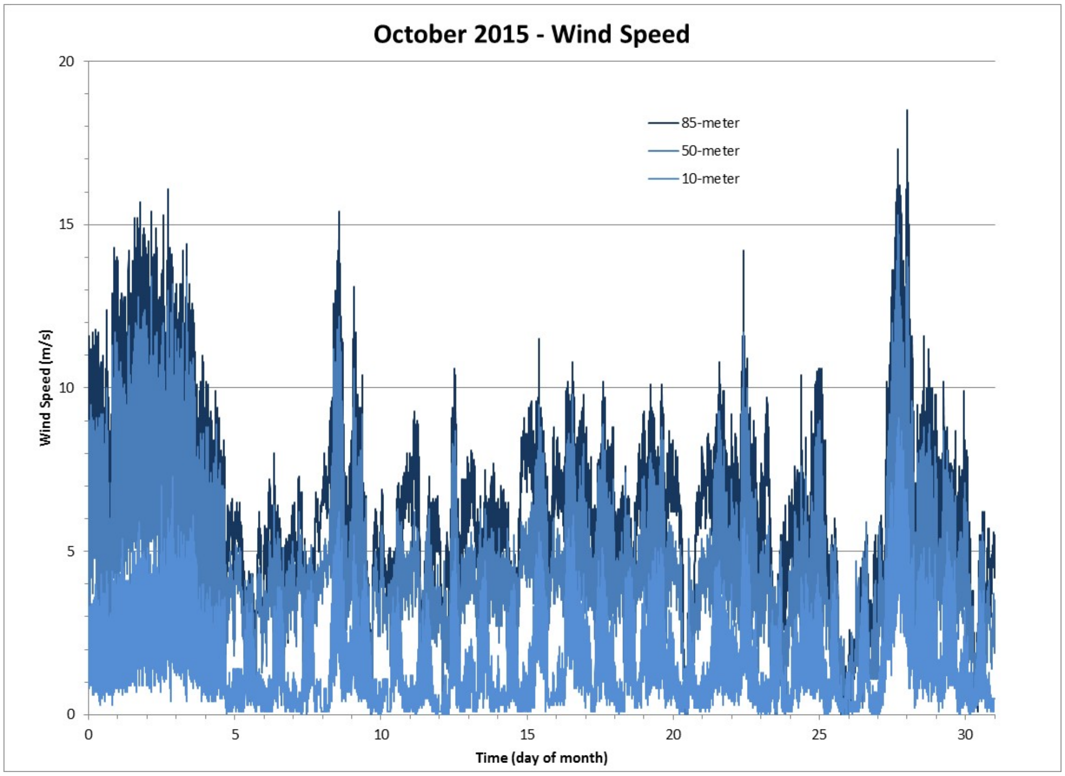

Figure 117 Wind Speed for the Month of October 2015

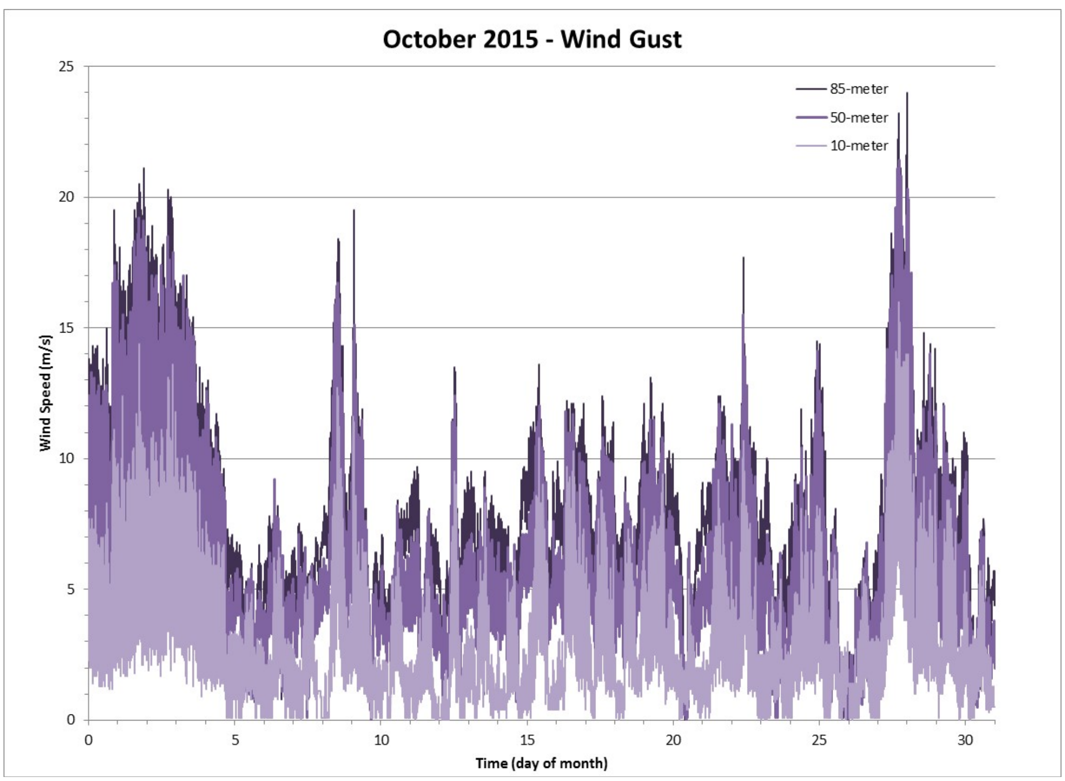

Figure 118 Wind Gust data for the Month of October 2015

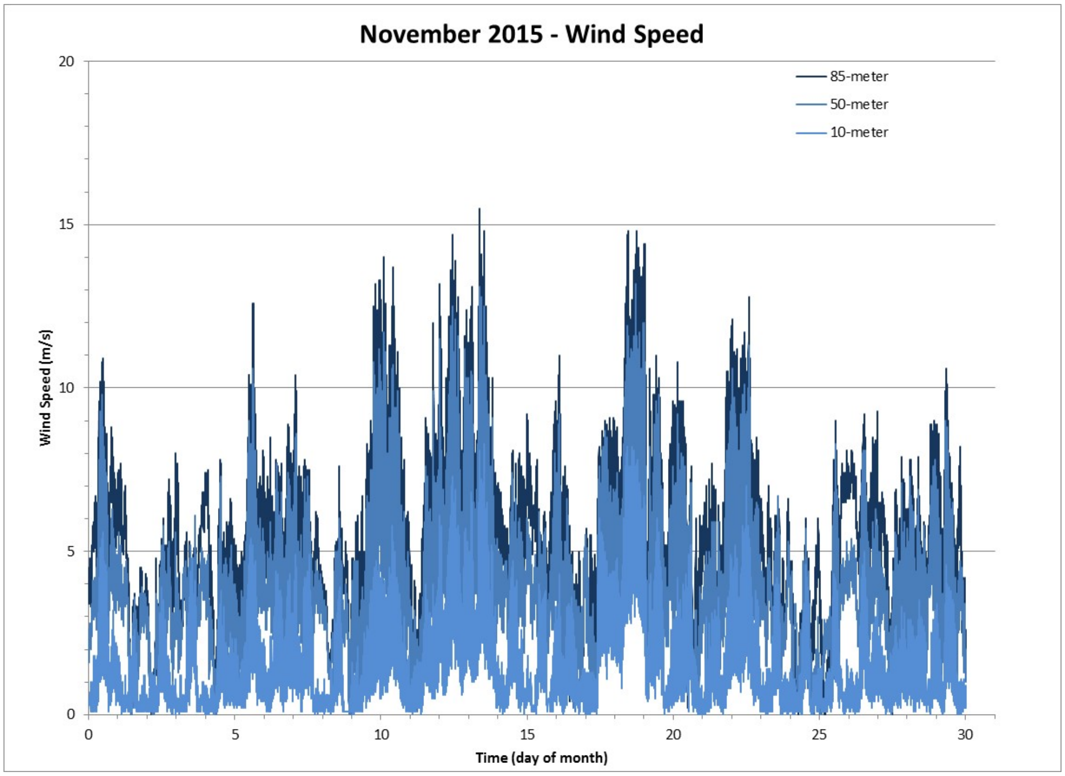

Figure 119 Wind Speed for the Month of November 2015

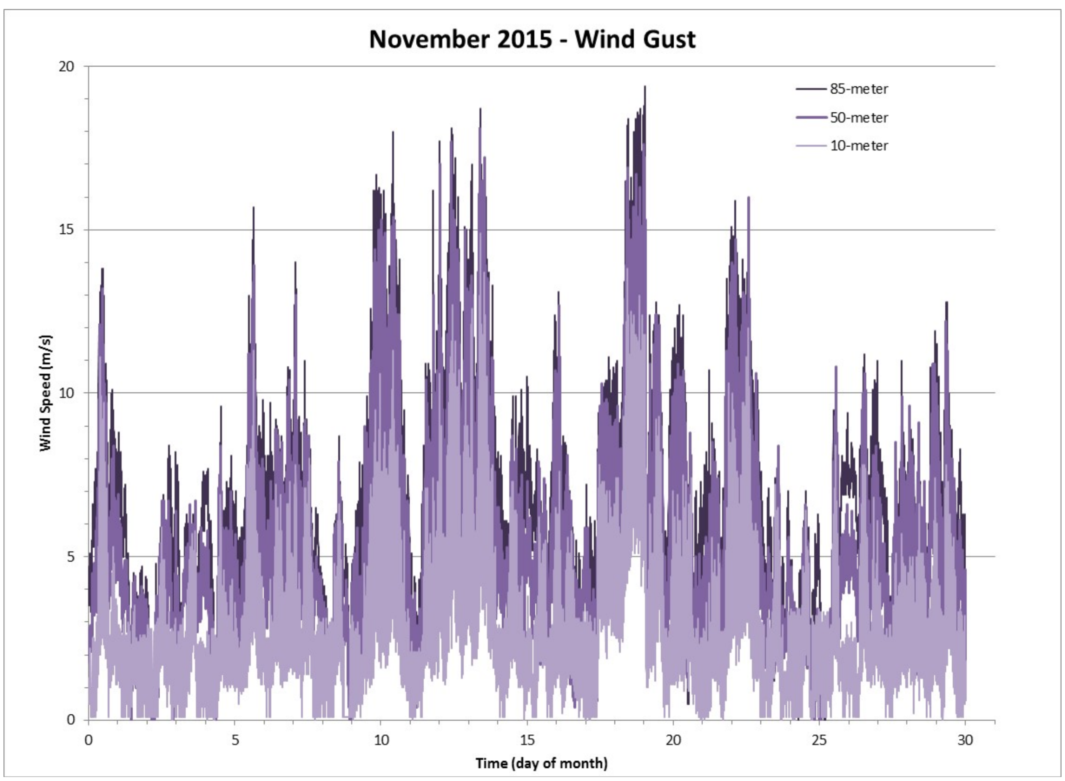

Figure 120 Wind Gust data for the Month of November 2015

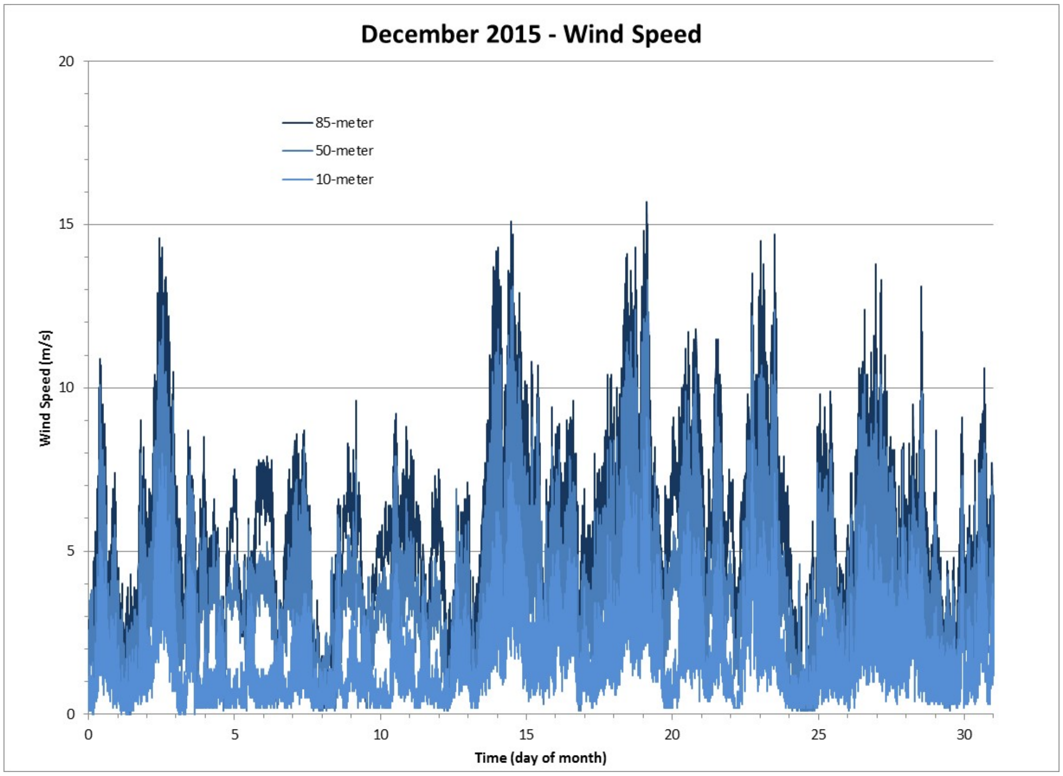

Figure 121 Wind Speed for the Month of December 2015

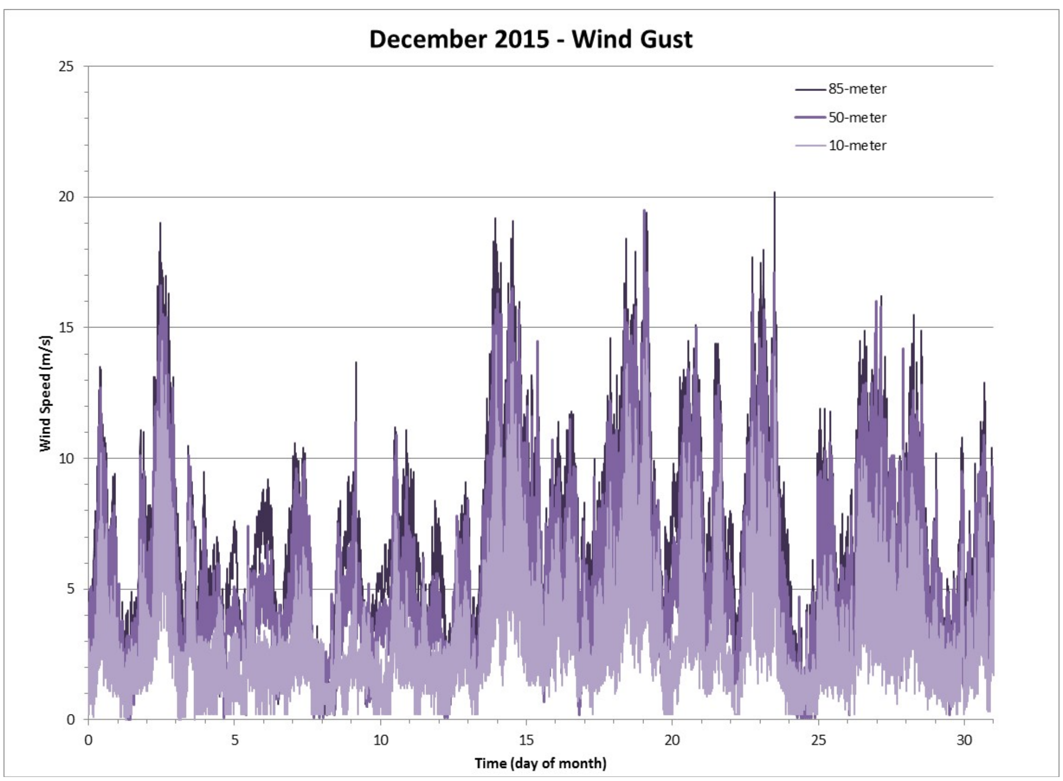

Figure 122 Wind Gust data for the Month of December 2015

2012 Solar Resource Data

High quality solar resource data is important to research in the field of renewable energy. With BNL being home to the Long Island Solar Farm (LISF) and future site of the Northeast Solar Energy Research Center (NSERC), it is important that BNL have a local source of dependable, quality assured data on solar radiation. As such BNL maintains a solar base station that records research grade one-minute data. This section reports solar incidence data including monthly data plots of the one-minute data.

Global Solar Radiation

Global solar irradiance is the total irradiance falling on a horizontal surface. It is the total of diffuse radiation plus the direct normal radiation multiplied by the cosine of the solar zenith angle. Global short-wave radiation (near ultraviolet, visible & near-infrared) is measured using a Kipp & Zonen CMP-22 pyranometer attached to a powered ventilator and mounted on a SOLYS-2 sun tracker. This unit is sent off-site for calibration in the NREL BORCAL program. Currently, when the unit is out for calibration it is replaced with a calibrated CMP-21 pyranometer. The CMP-21 is a high precision research grade pyranometer that includes an integrated housing temperature sensor. The CMP-22 is also a high precision research grade pyranometer with a higher optical quality and higher refractive index quartz dome housing the sensor. Figures 113 through 124 present the monthly plots of global solar radiation.

Figure 94 presents the peak global solar irradiance at BNL for 2012. Figure 95 presents the average daily global solar irradiance at BNL for 2012. Figure 96 shows the monthly average daily irradiance for global and in-plane (angled to match the LISF panels). Table 7 gives the 2012 and historical monthly daily averages for global solar irradiance.

Table 7 Average Daily Solar Irradiance (Global) at BNL by Month (W/m^2)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1994	72.2	116.7	147.7	207.9	246.9	265.2	259.8	193.4	187.5	152.3	92.6	72.5	167.9
1995	74.9	108.1	182.7	231.9	281.6	168.3	97.4	*301.1*	290.0	151.1	85.5	77.4	170.8
1996	63.2	113.9	171.6	193.7	242.0	239.0	222.8	227.1	158.6	145.2	92.9	*52.5*	160.2
1997	80.1	119.4	152.4	226.6	261.3	283.7	288.6	225.2	180.4	145.4	78.4	70.8	176.0
1998	72.4	113.4	146.5	215.0	243.3	283.5	268.4	255.5	204.3	139.5	98.3	64.7	175.4
1999	73.5	114.4	195.3	223.2	249.6	285.3	270.1	223.9	219.4	156.0	97.1	77.6	182.1
2000	82.7	122.4	182.8	171.7	278.3	267.5	265.5	212.8	208.4	194.6	120.7	81.9	182.4
2001	81.7	125.1	148.3	220.6	289.4	281.5	284.2	227.5	202.6	159.3	105.9	74.7	183.4
2002	78.0	162.4	161.2	230.5	264.4	289.4	291.7	271.6	191.7	122.8	78.8	70.3	184.4
2003	83.9	74.3	174.1	191.8	190.4	262.6	249.8	294.6	175.3	118.8	80.4	58.8	162.9
2004	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2005	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2006	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2007	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2008	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2009	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2010	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan	nan
2011	86.2	121.1	177.5	172.6	223.6	254.2	276.7	223.7	130.0	130.3	97.5	75.2	164.1
2012	91.5	126.5	163.7	254.3	199.2	268.3	249.0	231.8	179.6	110.0	92.8	59.8	168.9
2013	82.6	109.8	163.0	243.9	236.7	256.7	239.0	210.4	189.8	128.6	96.1	60.9	168.1
2014	80	121	159	223	237	277	263	239	185	116	86	56	170
2015	80	119	161	211	262	233	252	250	200	137	88	57	171
Average	**79**	**118**	**166**	**215**	**247**	**261**	**252**	**239**	**194**	**140**	**93**	**67**	**173**
Max	92	162	195	254	289	289	292	*301*	290	195	121	82	184
Min	63	74	147	172	190	168	97	193	130	110	78	*53*	160

nan indicates missing data, Values in fields filled in yellow are the monthly averages inserted because of partially missing data, the average then changes with addition of this value.

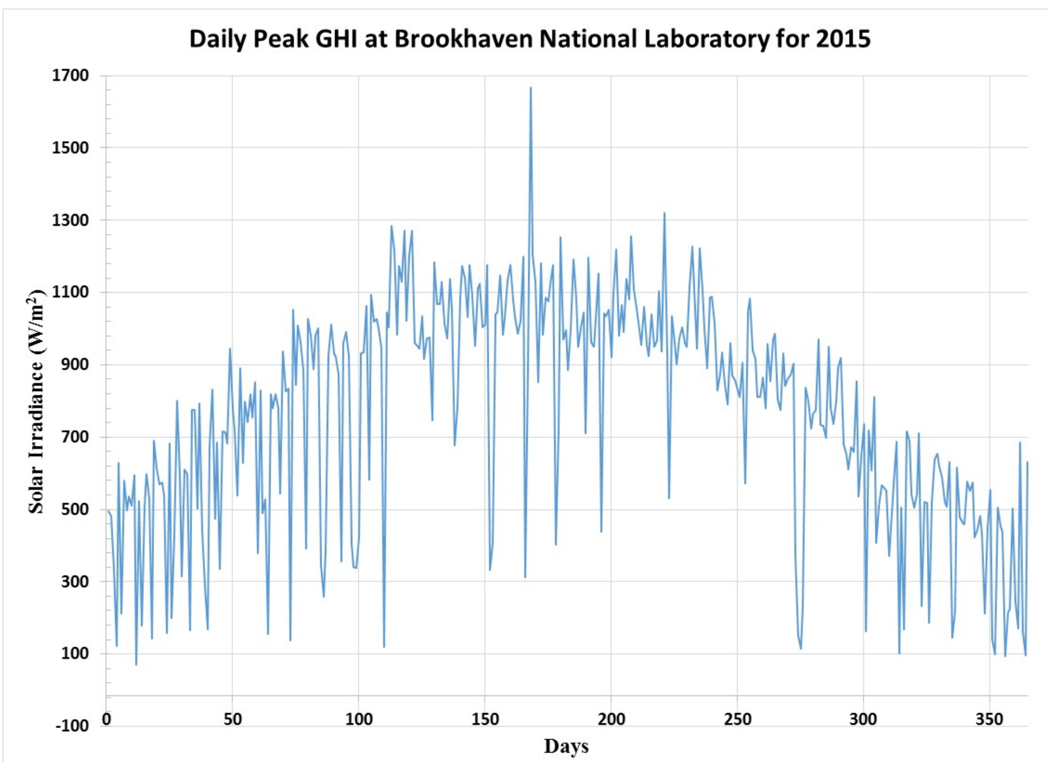

Figure 123 Daily Peak Solar Irradiance at Brookhaven National Laboratory for 2015

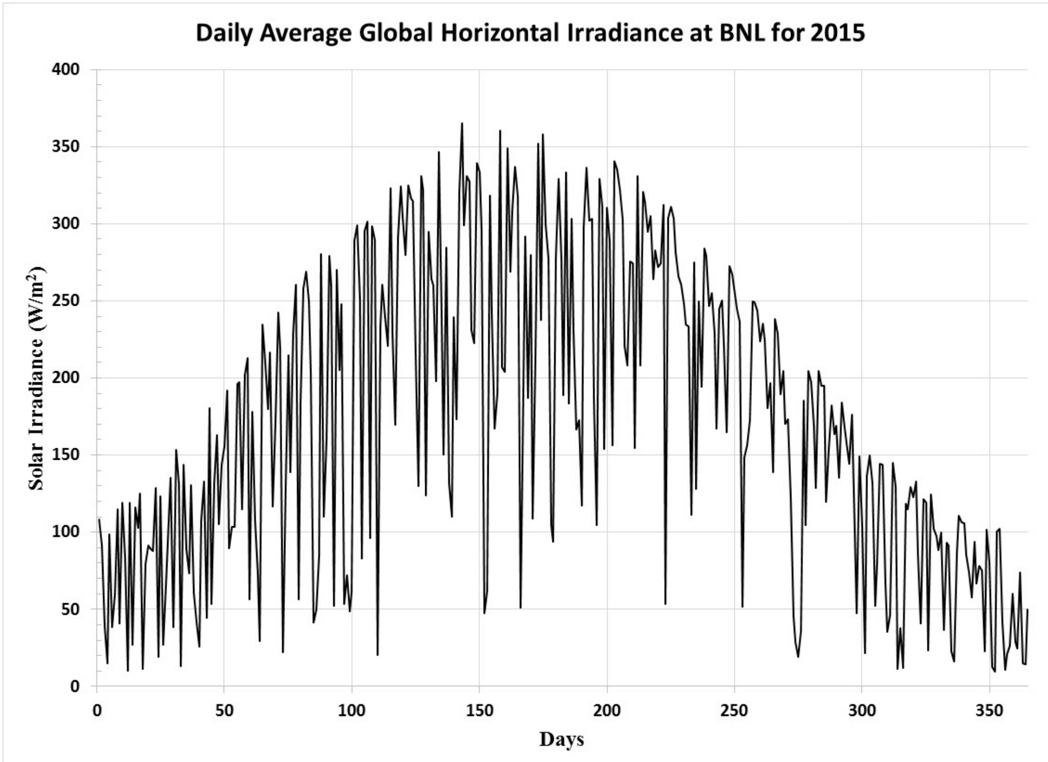

Figure 124 Average Daily Solar Irradiance at Brookhaven National Laboratory for 2015

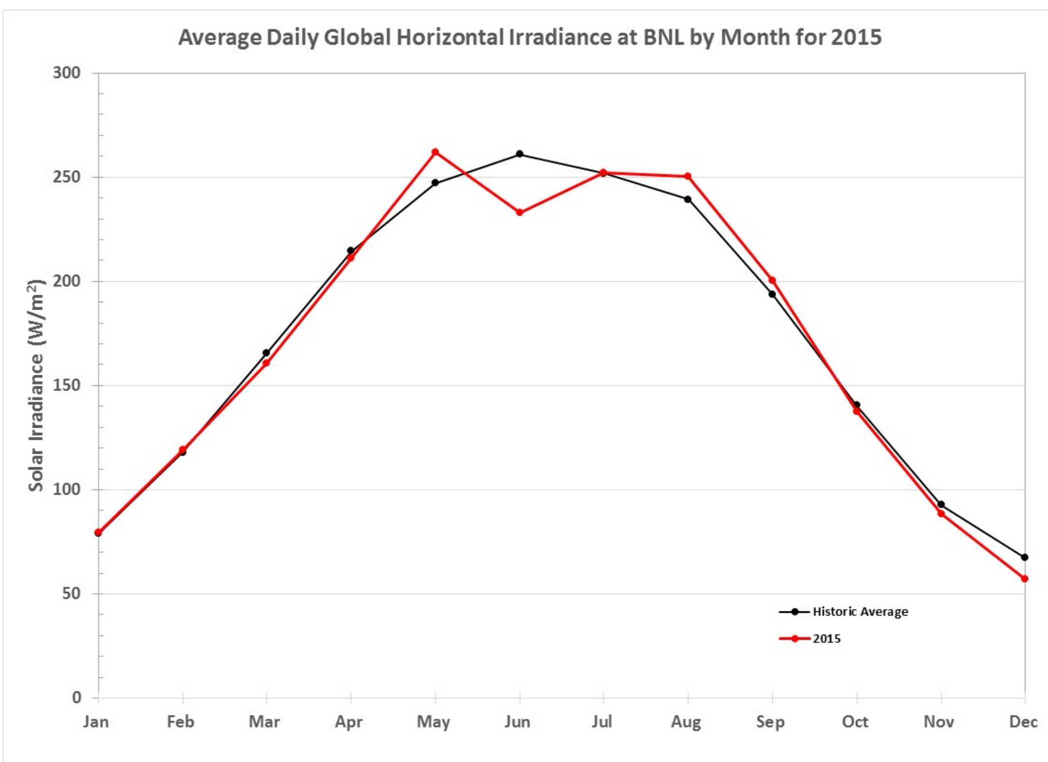

Figure 125 Global Horizontal Irradiance – 2015 Monthly Daily-Average

Diffuse Solar Radiation

Diffuse solar irradiance is the radiation that is scattered (i.e., by clouds and dust particles) as it passes through the atmosphere. Diffuse short-wave radiation (ultraviolet, visible & near-infrared) is measured using a shaded Kipp & Zonen CMP-22 pyranometer with a powered ventilator mounted on a SOLYS-2 sun tracker. This unit is sent off-site for calibration in the NREL BORCAL program. Currently, when the unit is out for calibration it is replaced with a calibrated CMP-21 pyranometer. Figures 125 through 136 present the monthly plots of diffuse solar radiation.

Direct Solar Radiation

Direct solar irradiance is the solar radiation that travels in a straight path to a detector that is perpendicular to the light path. The direct short-wave radiation is measured with a Kipp & Zonen CHP-1 pyrheliometer attached to a SOLYS-2 sun tracker. The CHP-1 is a thermopile that absorbs 97-98% of the total incident radiation. The reported maximum uncertainty is 2% for hourly measurements and 1% for daily totals. Figures 137 through 148 present the monthly plots of direct solar radiation.

Long-wave Far Infrared Radiation

Downward long-wave far infrared radiation is measured using a shaded Kipp & Zonen CGR-4 pyrgeometer with a powered ventilator mounted on the SOLYS-2 sun tracker. The CGR-4 is a research grade thermopile. This unit is sent off-site for calibration in the NREL BORCAL program. A duplicate unit is stocked which is sent to NREL for calibration and replaces the in service unit when returned. The CGR-4 has a built in temperature sensor and temperature correction is applied. The reported maximum daily uncertainty is 3%. Figures 149 through 160 present the monthly plots of direct solar radiation.

LISF and NSERC Reference Pyranometers

The Long Island Solar Farm (LISF) and NorthEast Solar Research Center (NSERC) both have a network of pyranometers and meteorological sensors to provide data for solar research. Each of the 25 LISF powerblocks and the three areas of NSERC has a pair of Kipp & Zonen pyranometers that measure global and tilted global solar radiation. As a reference for the LISF sensor array, two Kipp and Zonen model SP-lite2 pyranometers are maintained at the base station on building 490D, one in-plane (tilted global radiation) at the 27° angle of inclination used for the panels at the LISF and one horizontal (global radiation). A corresponding set of SP-lite2 pyranometers are maintained for the NSERC with the in-plane at an angle of 23°. The horizontal (global) solar radiation plots are presented in Figures 161 through 172. The in-plane or tilted global radiation is presented in Figures 173 through 189.

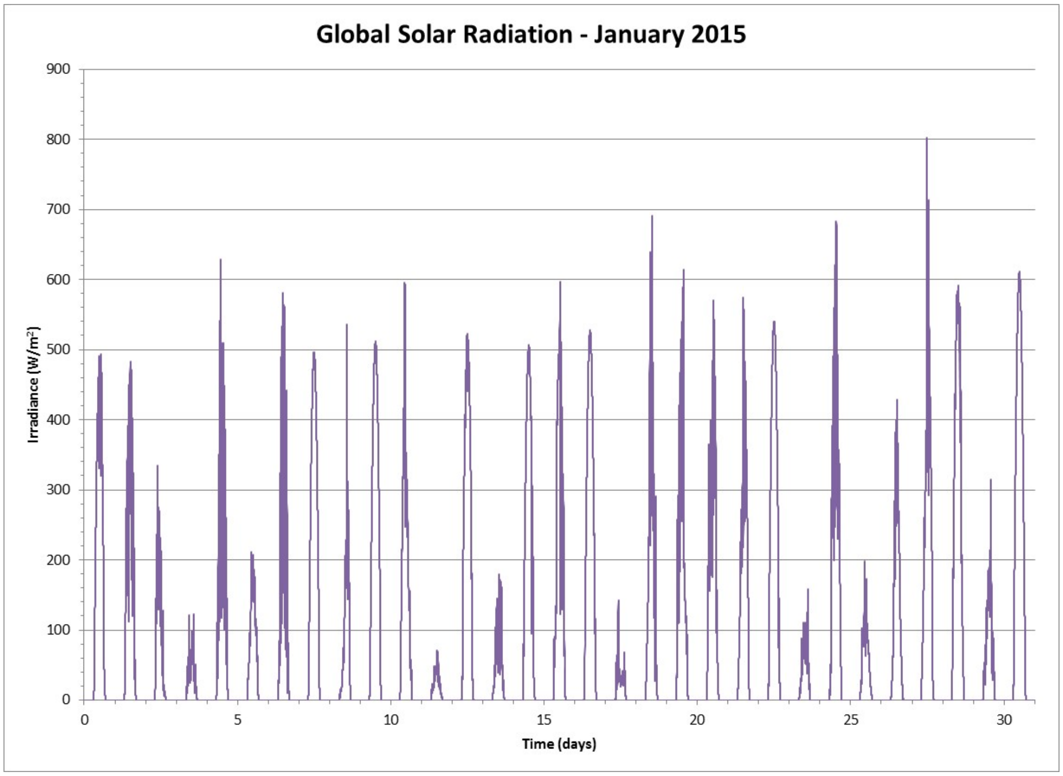

Figure 126 Global Solar Radiation for the Month of January 2015

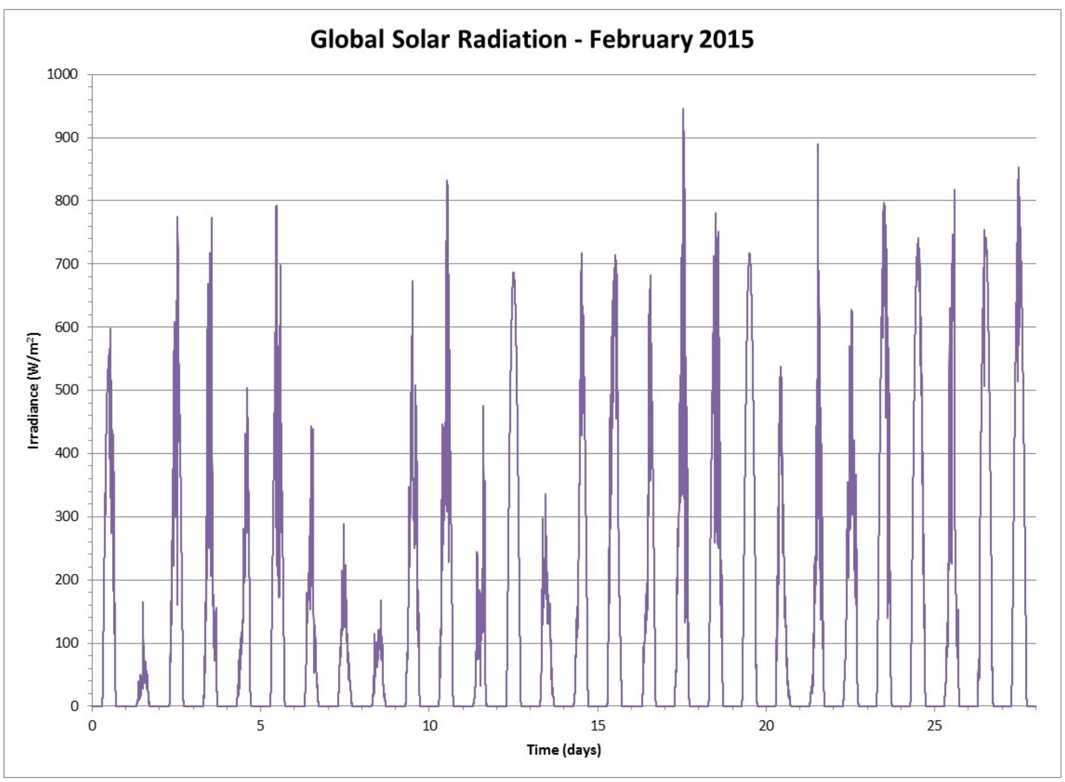

Figure 127 Global Solar Radiation for the Month of February 2015

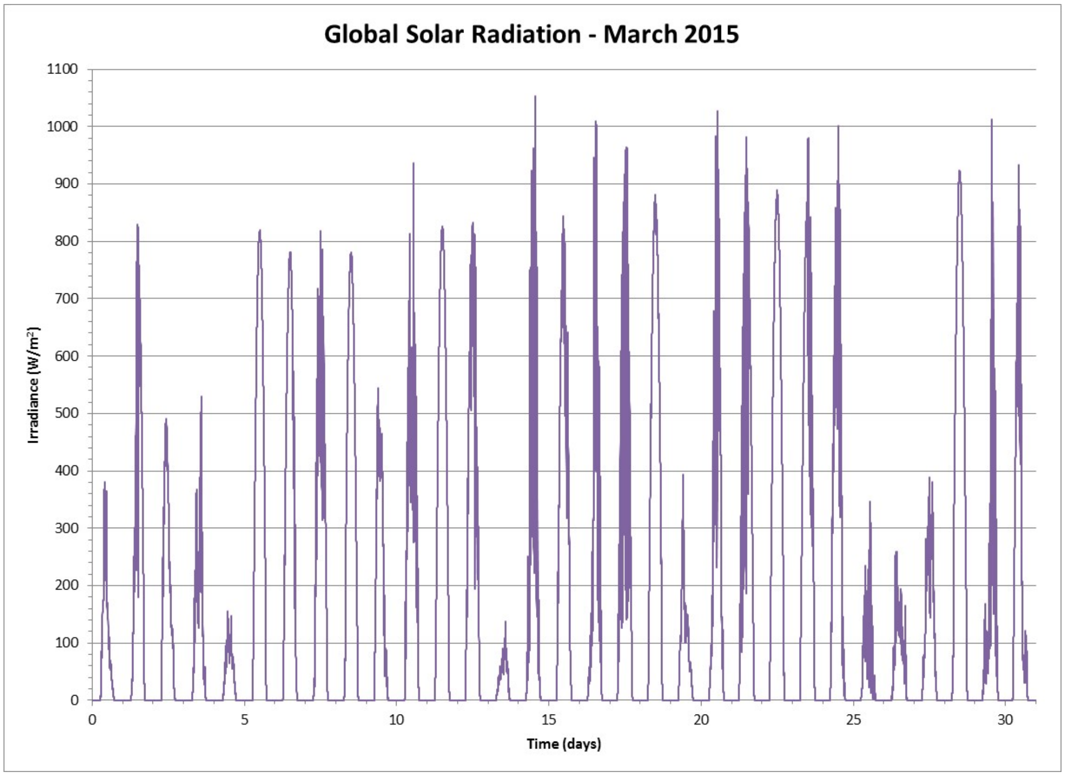

Figure 128 Global Solar Radiation for the Month of March 2015

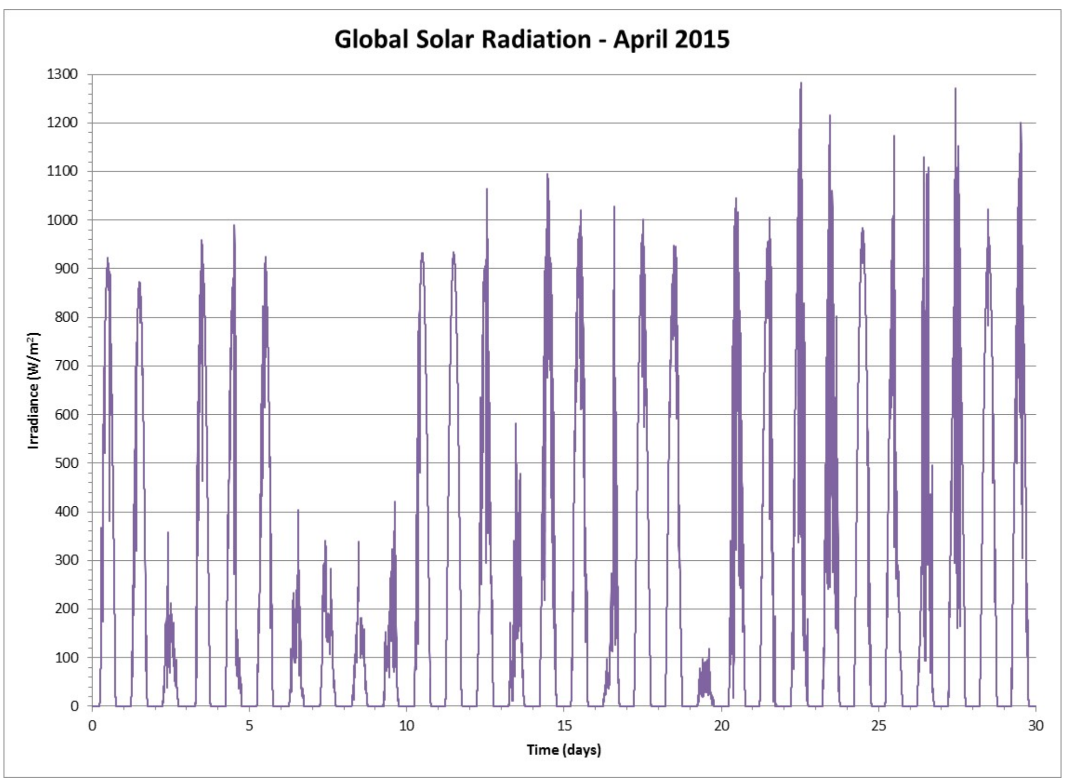

Figure 129 Global Solar Radiation for the Month of April 2015

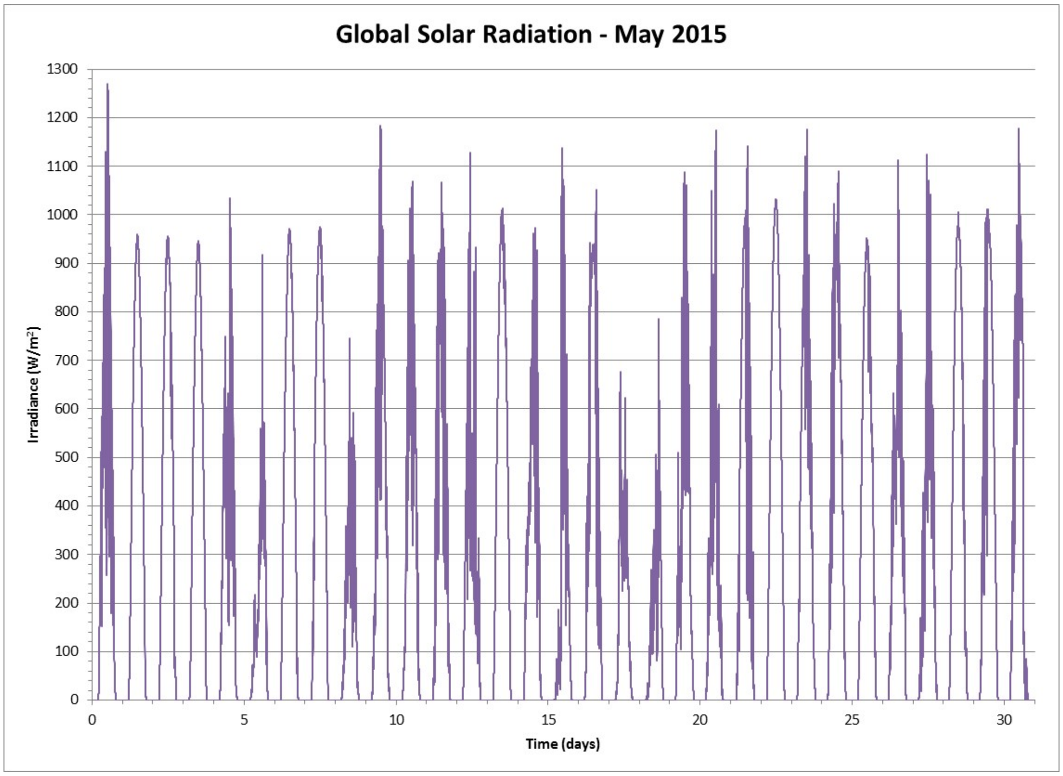

Figure 130 Global Solar Radiation for the Month of May 2015

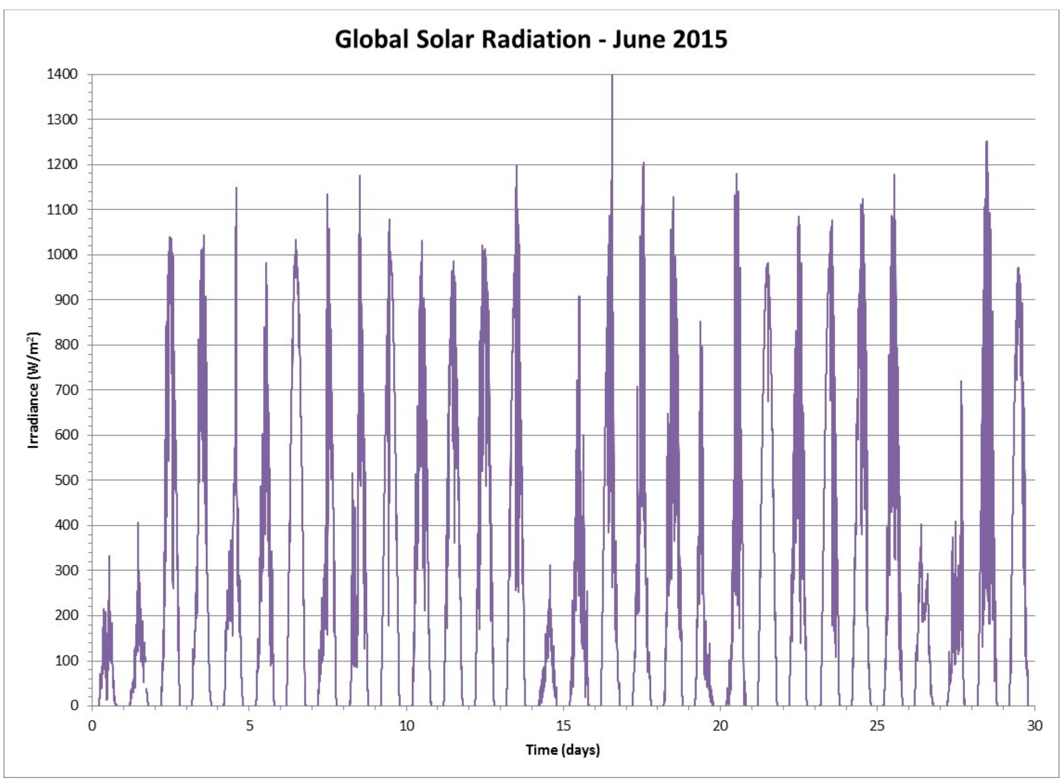

Figure 131 Global Solar Radiation for the Month of June 2015

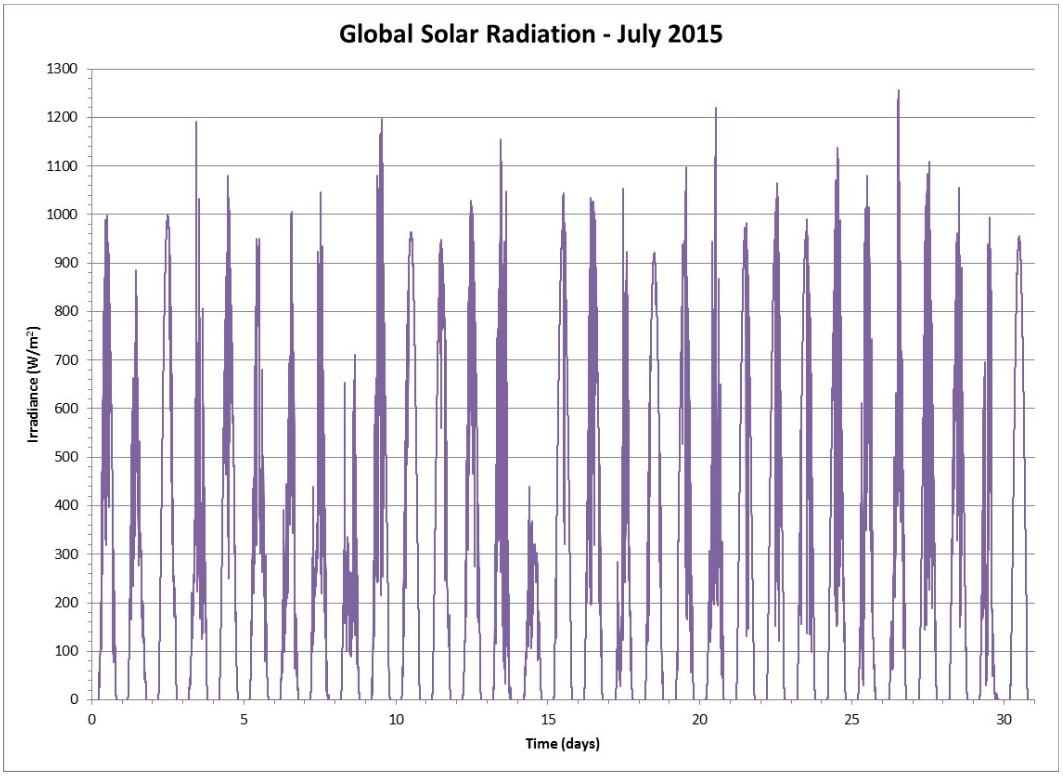

Figure 132 Global Solar Radiation for the Month of July 2015

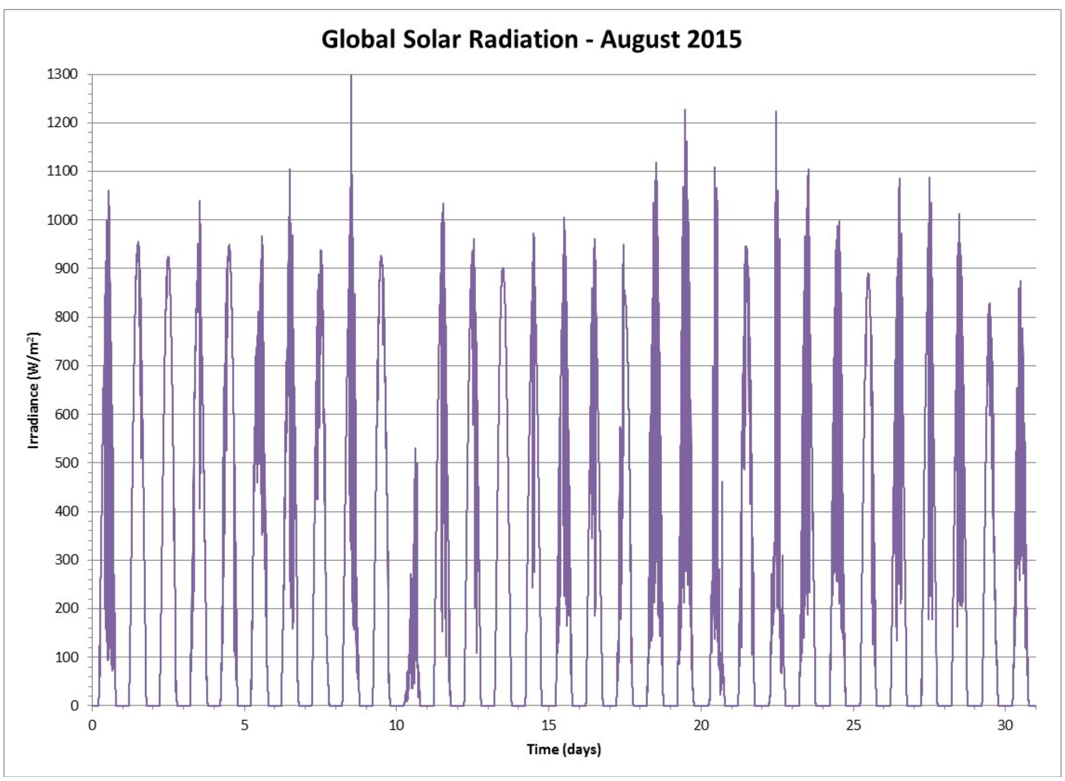

Figure 133 Global Solar Radiation for the Month of August 2015

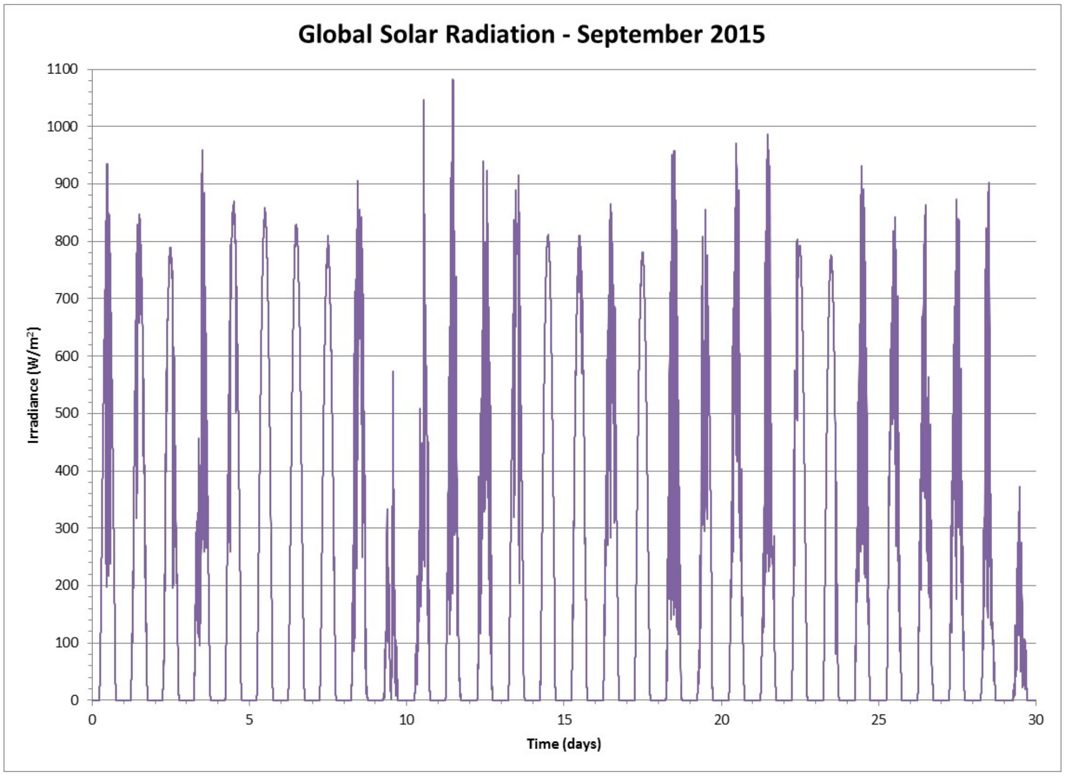

Figure 134 Global Solar Radiation for the Month of September 2015

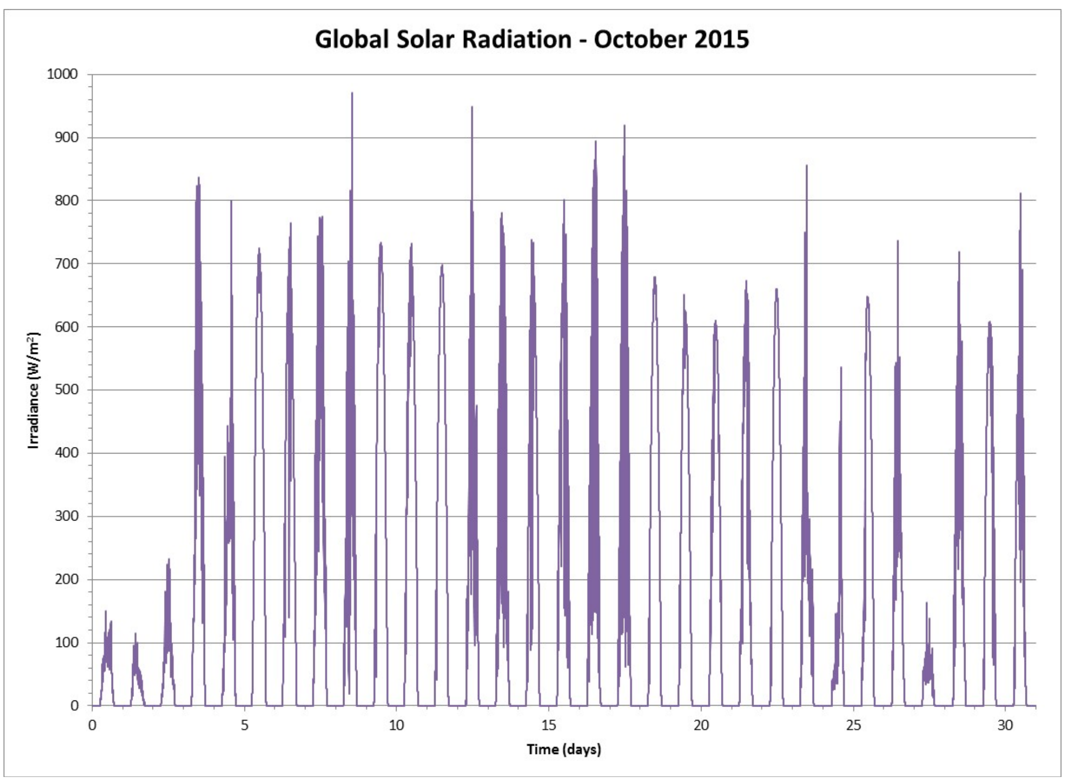

Figure 135 Global Solar Radiation for the Month of October 2015

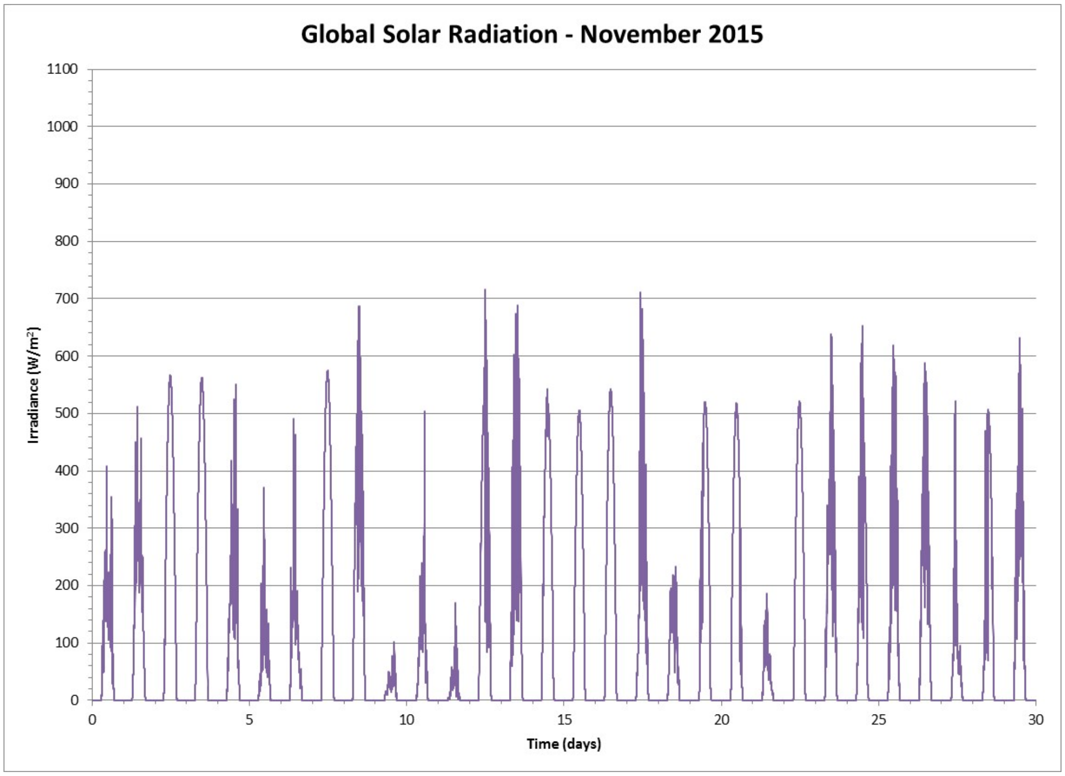

Figure 136 Global Solar Radiation for the Month of November 2015

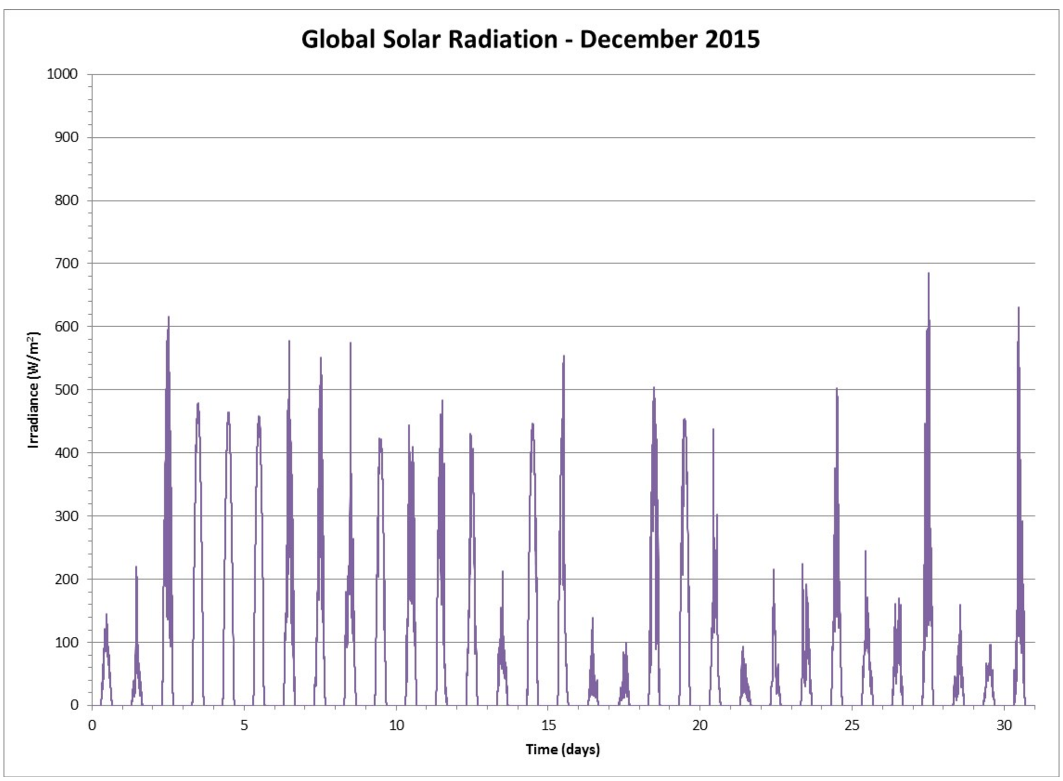

Figure 137 Global Solar Radiation for the Month of December 2015

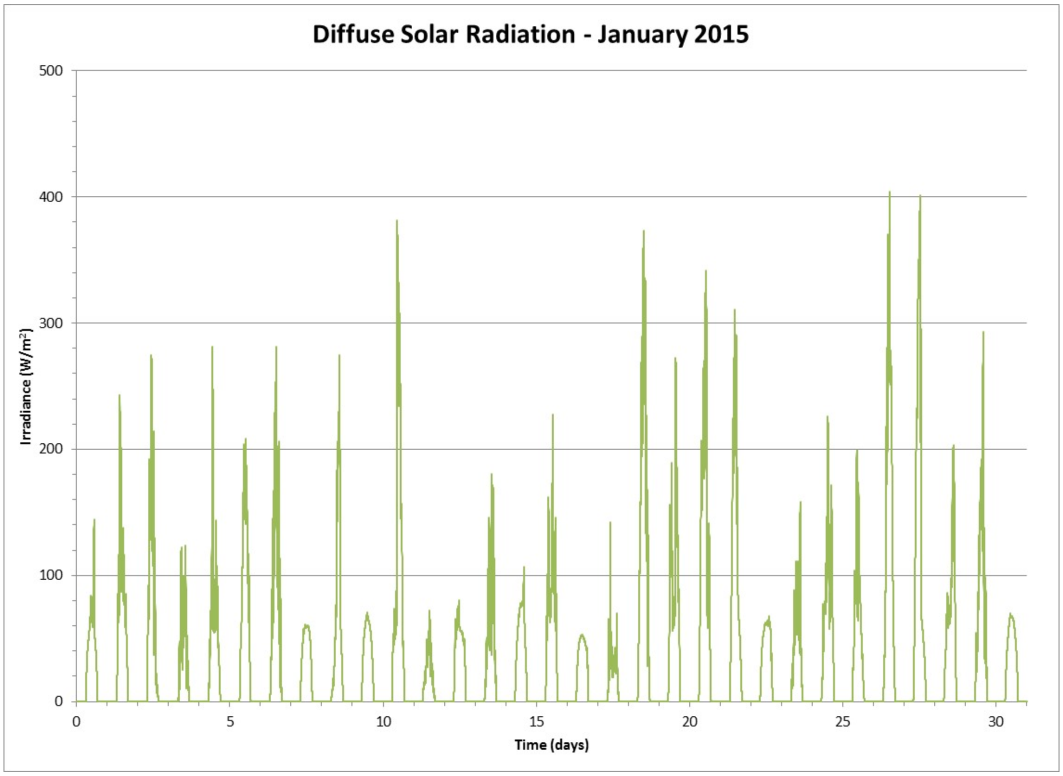

Figure 138 Diffuse Solar Radiation for the Month of January 2015

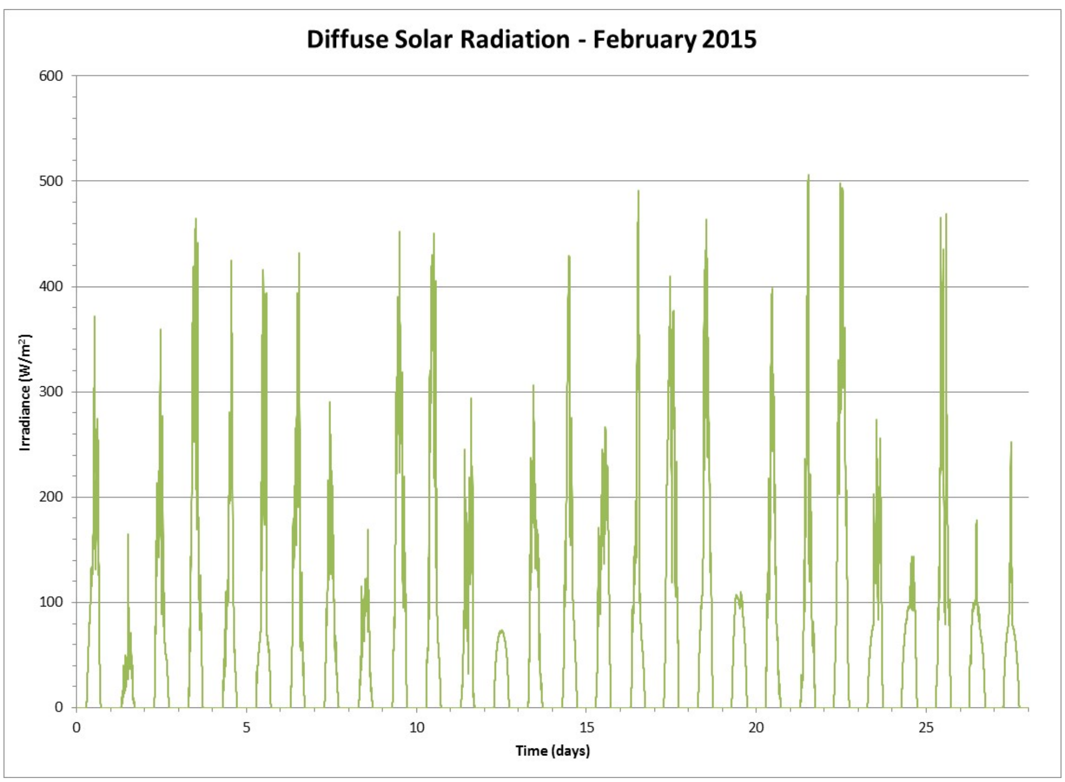

Figure 139 Diffuse Solar Radiation for the Month of February 2015

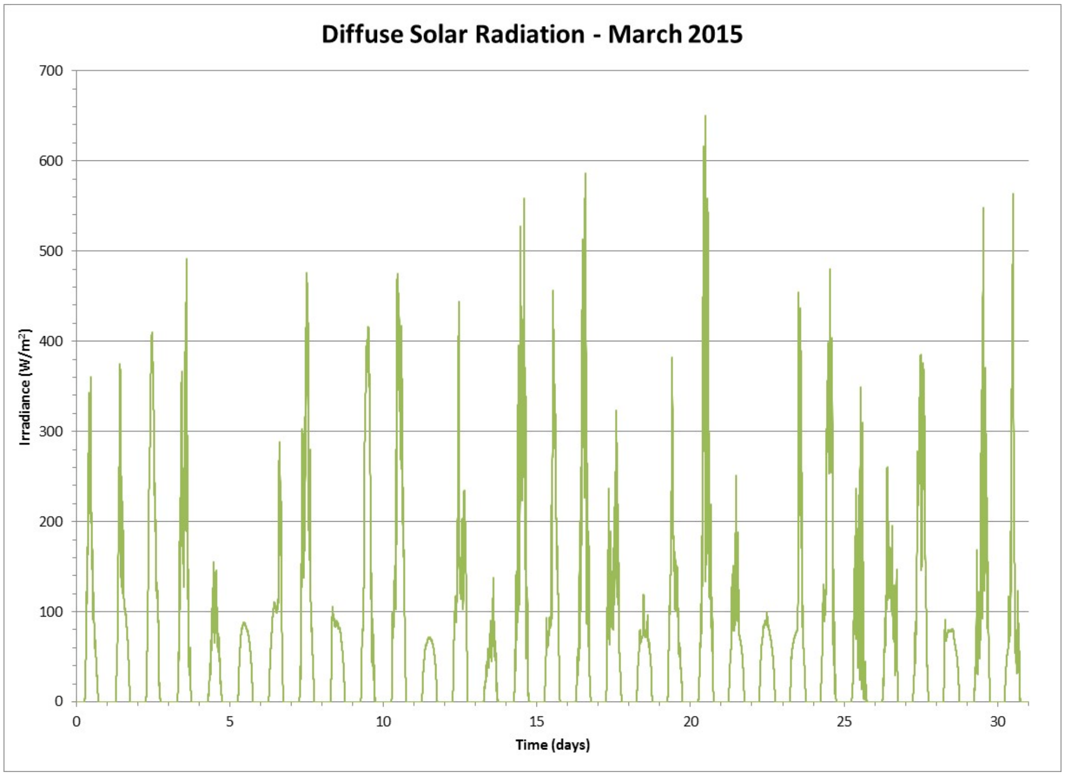

Figure 140 Diffuse Solar Radiation for the Month of March 2015

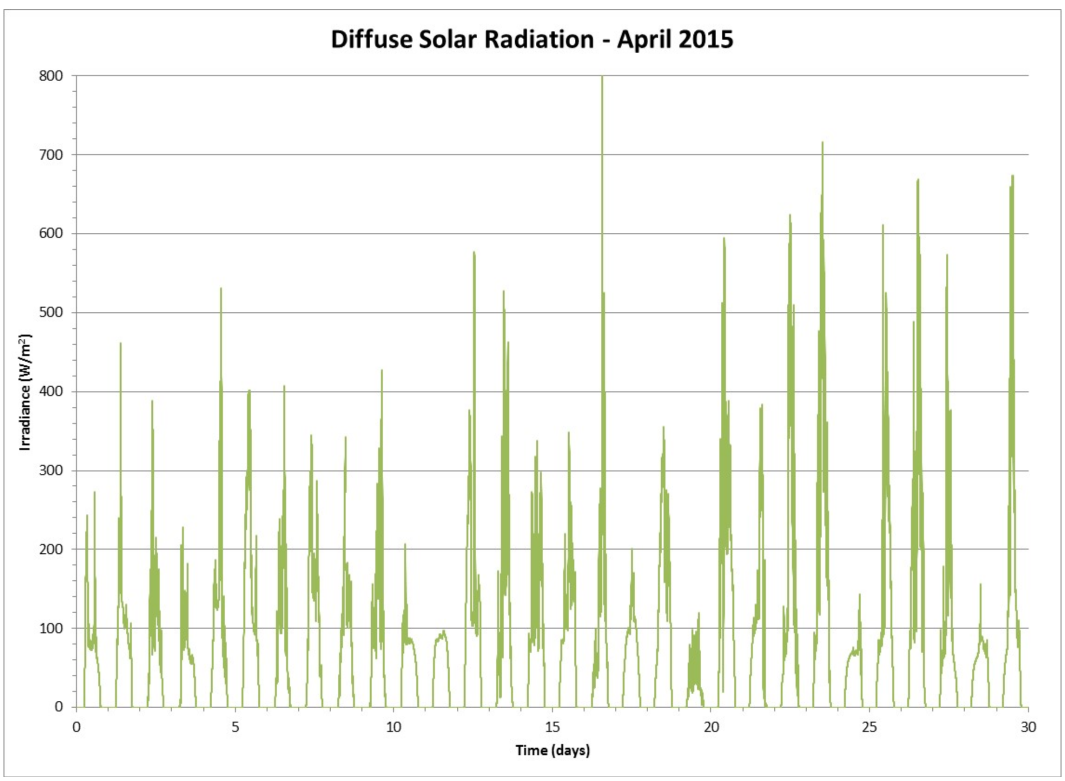

Figure 141 Diffuse Solar Radiation for the Month of April 2015

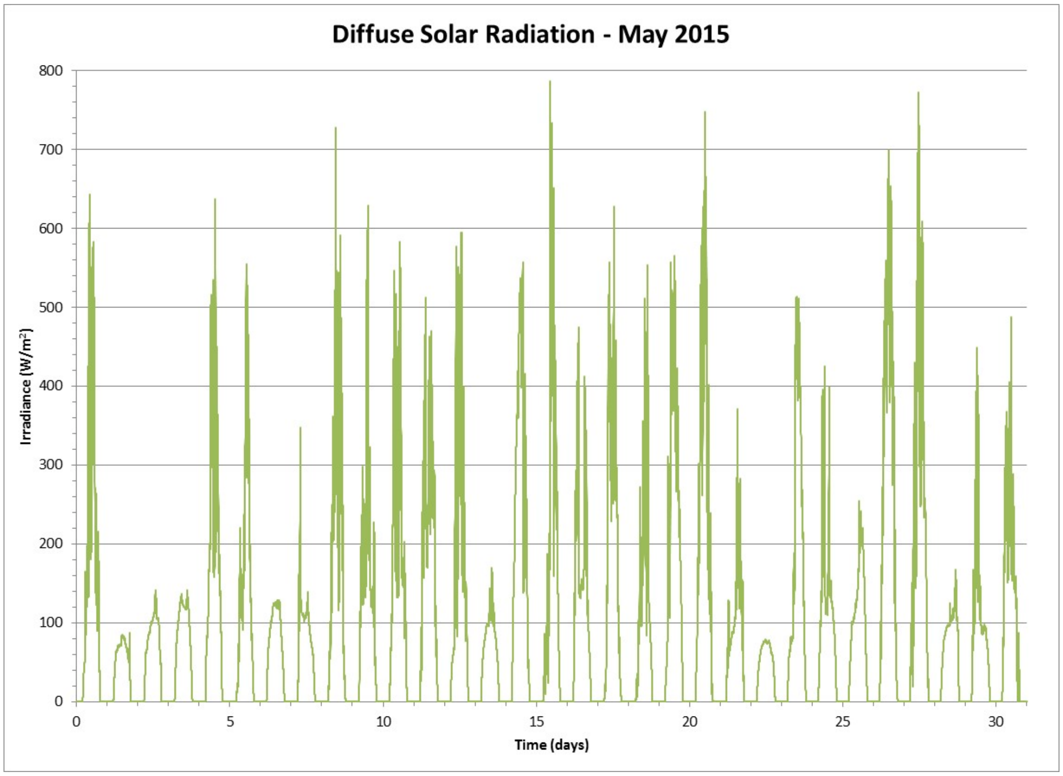

Figure 142 Diffuse Solar Radiation for the Month of May 2015

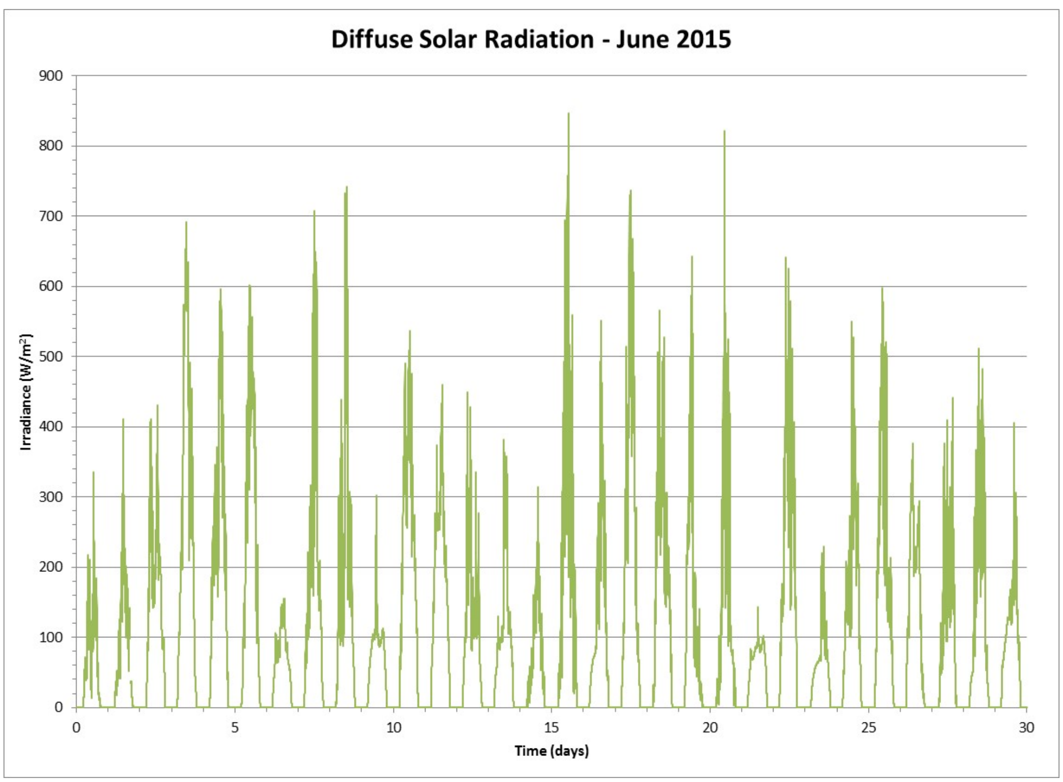

Figure 143 Diffuse Solar Radiation for the Month of June 2015

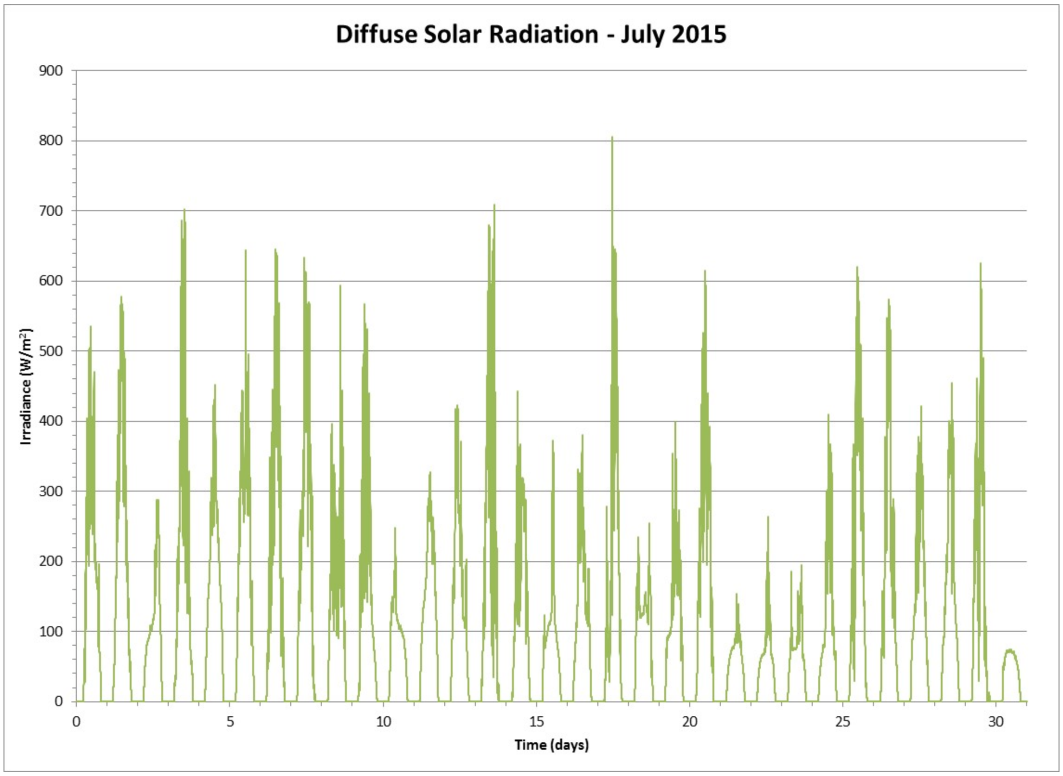

Figure 144 Diffuse Solar Radiation for the Month of July 2015

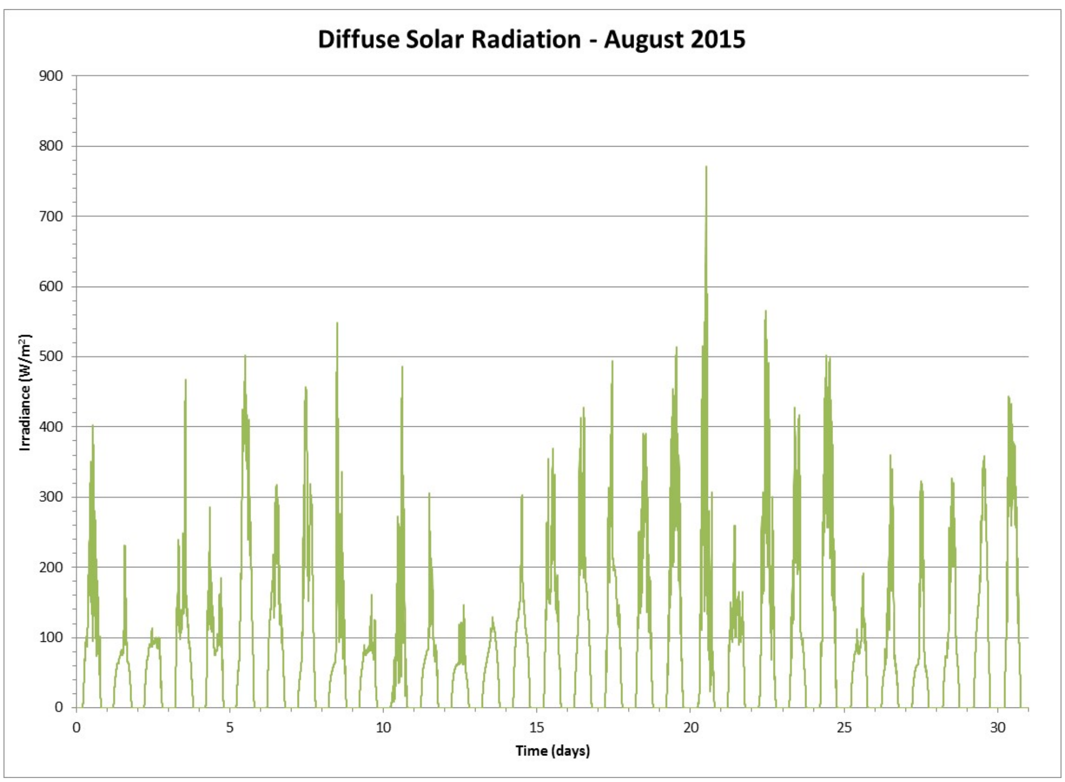

Figure 145 Diffuse Solar Radiation for the Month of August 2015

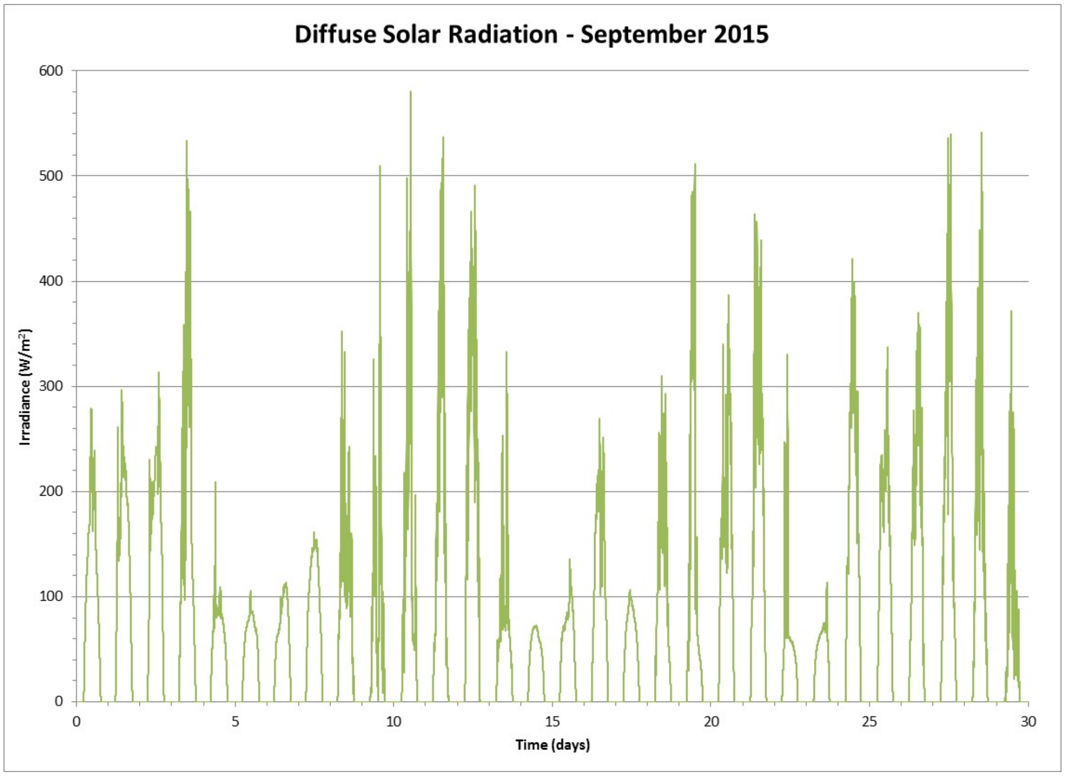

Figure 146 Diffuse Solar Radiation for the Month of September 2015

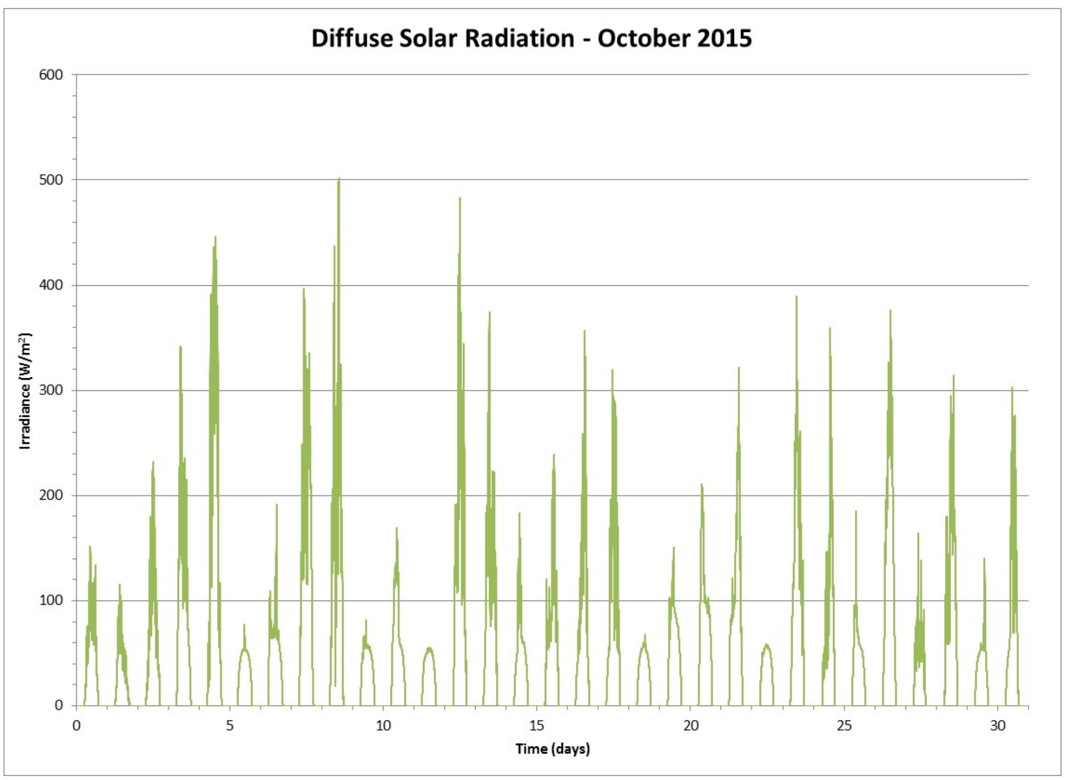

Figure 147 Diffuse Solar Radiation for the Month of October 2015

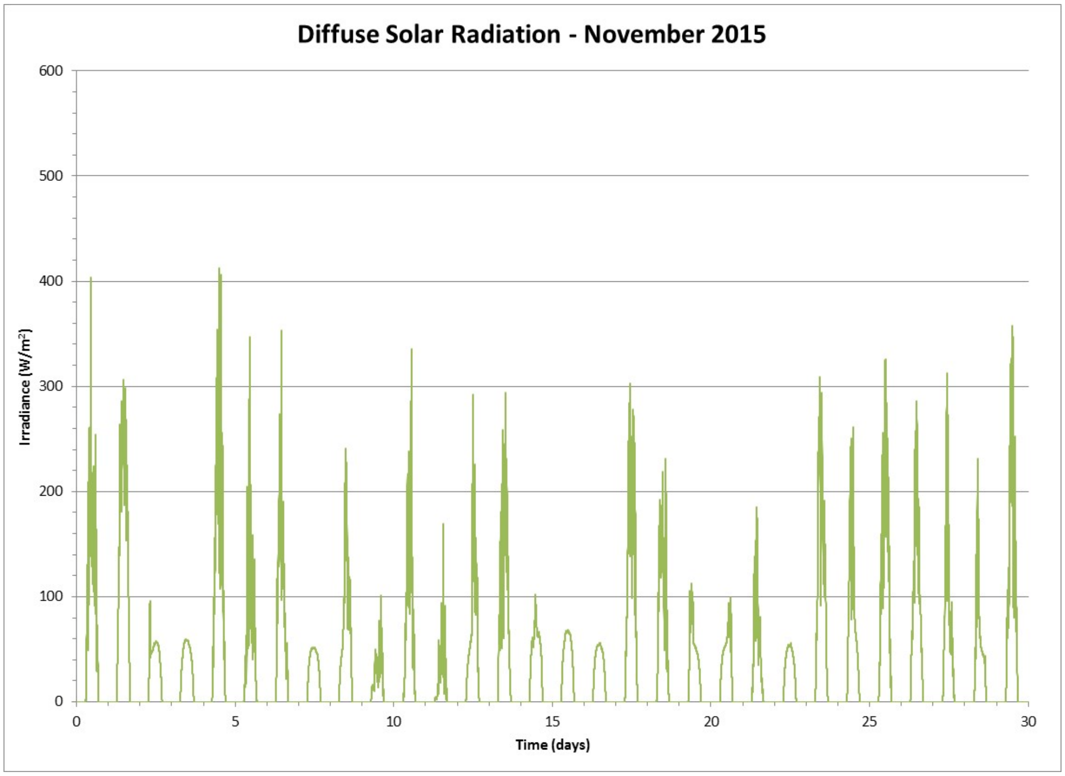

Figure 148 Diffuse Solar Radiation for the Month of November 2015

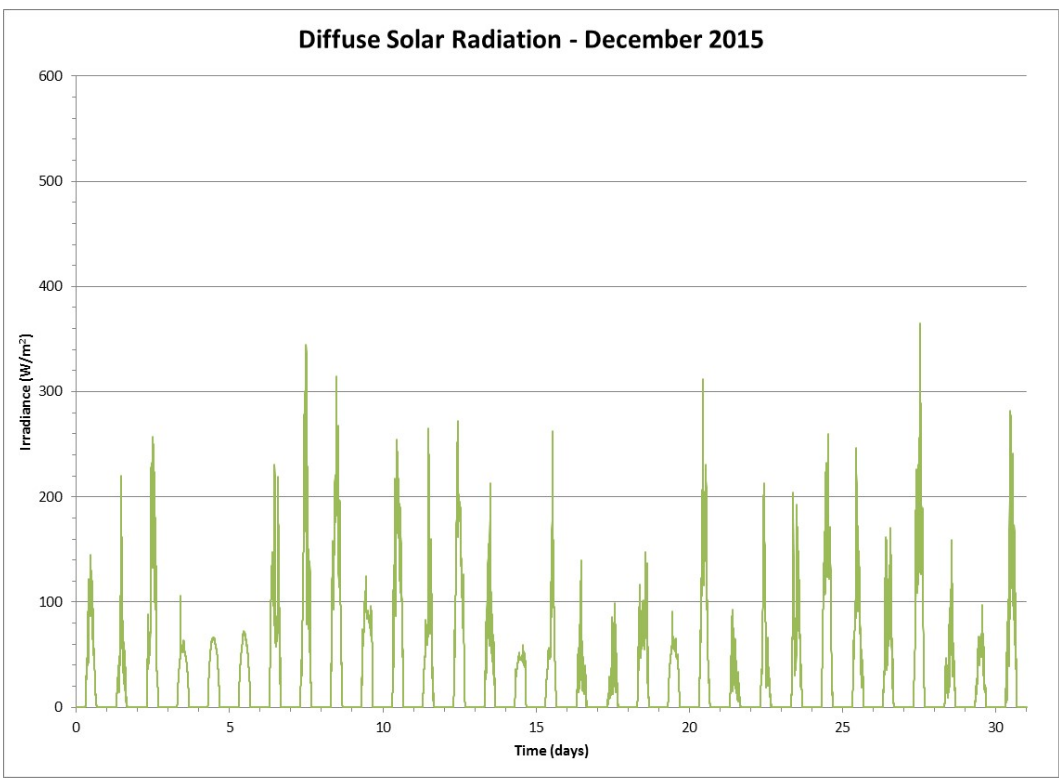

Figure 149 Diffuse Solar Radiation for the Month of December 2015

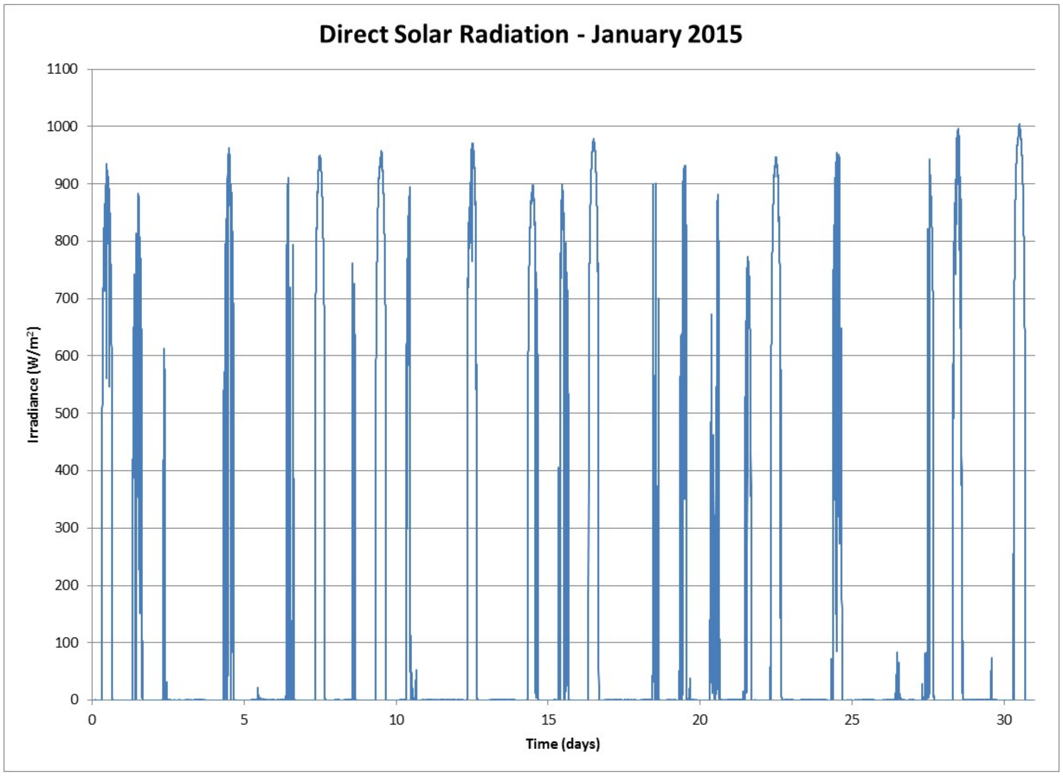

Figure 150 Direct Solar Radiation for the Month of January 2015

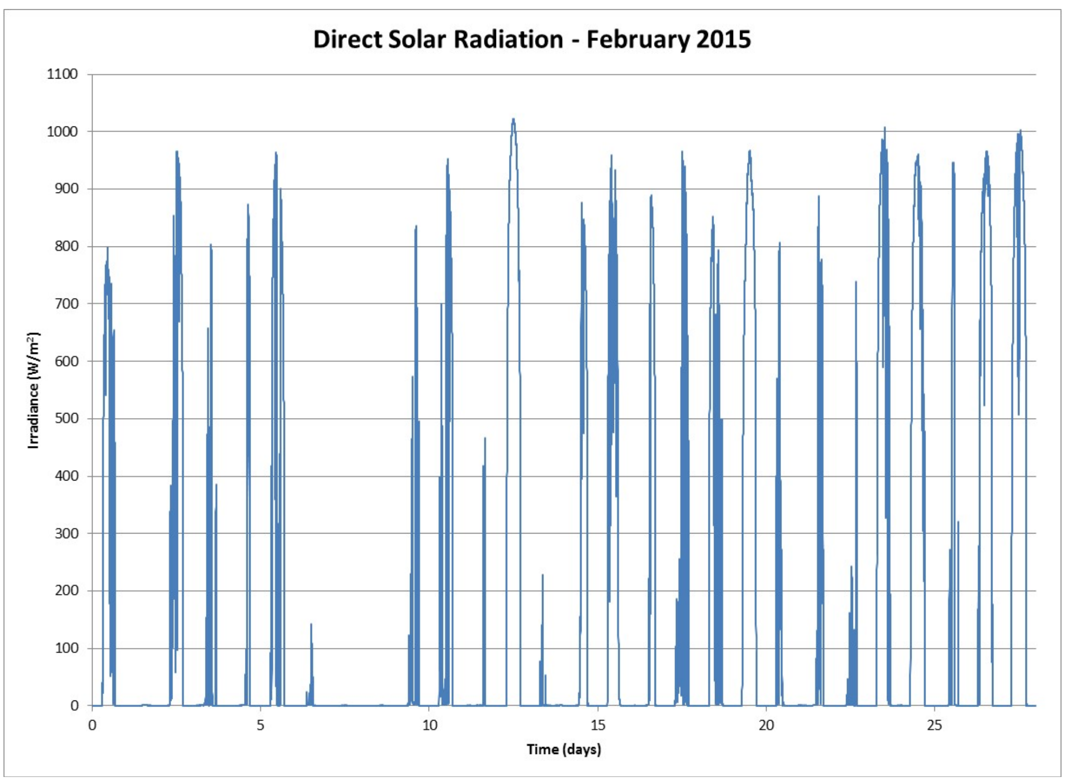

Figure 151 Direct Solar Radiation for the Month of February 2015

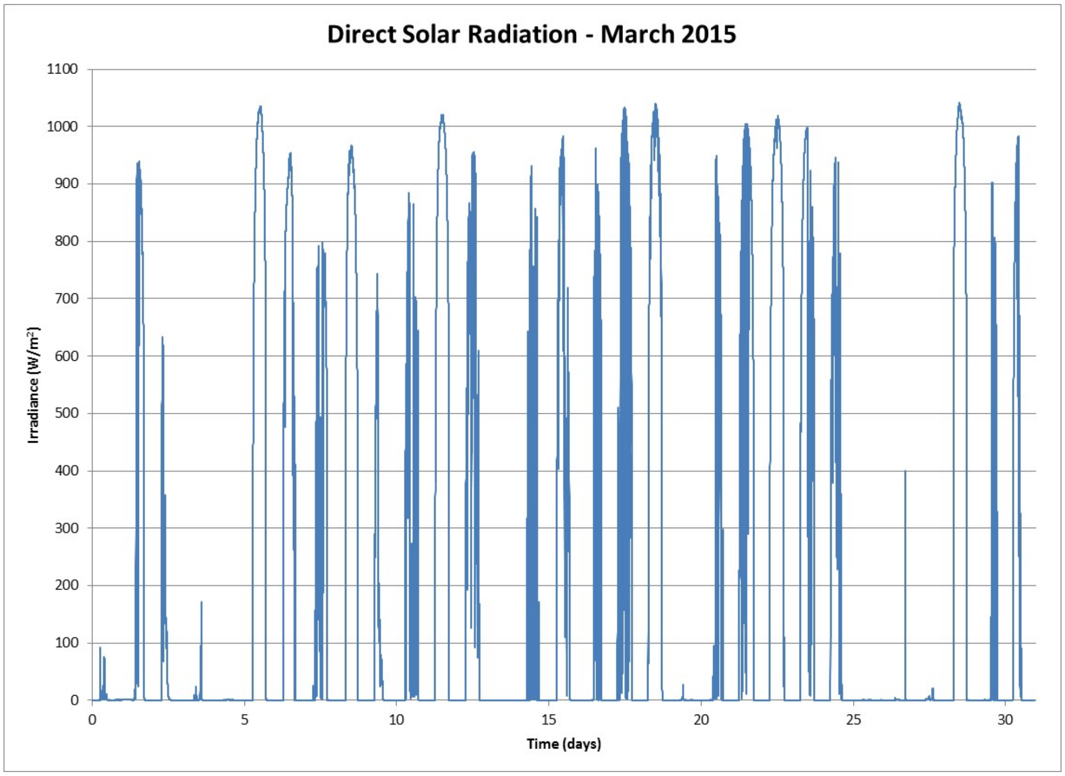

Figure 152 Direct Solar Radiation for the Month of March 2015

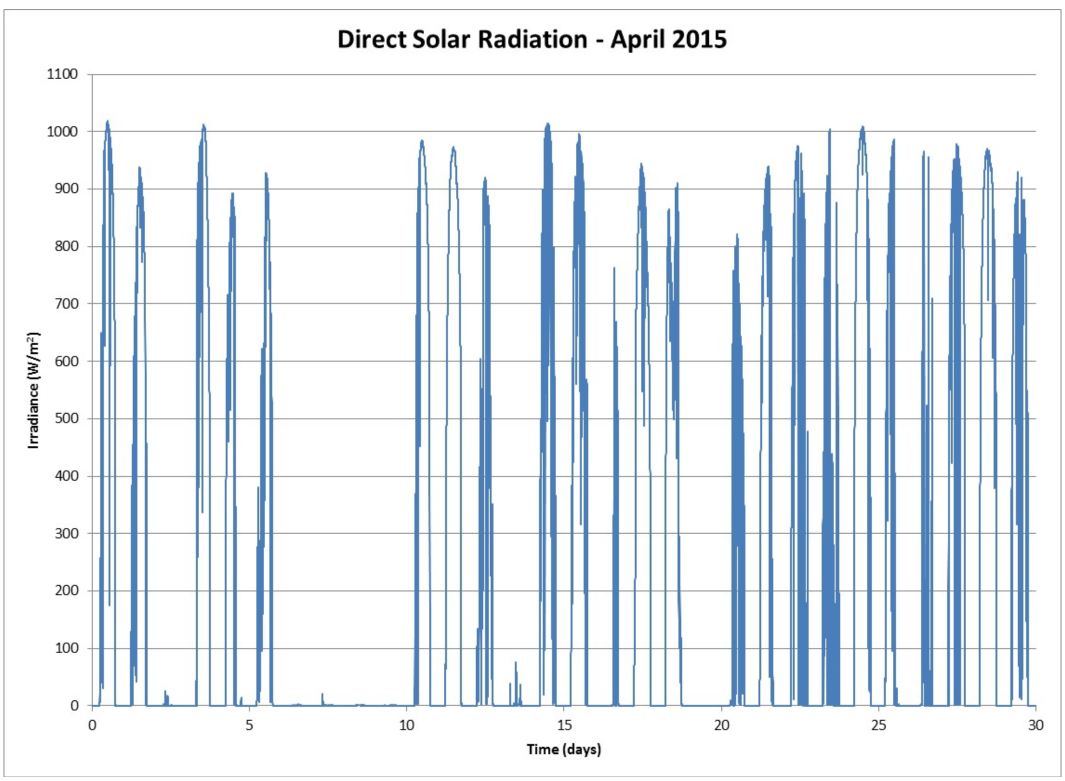

Figure 153 Direct Solar Radiation for the Month April 2015

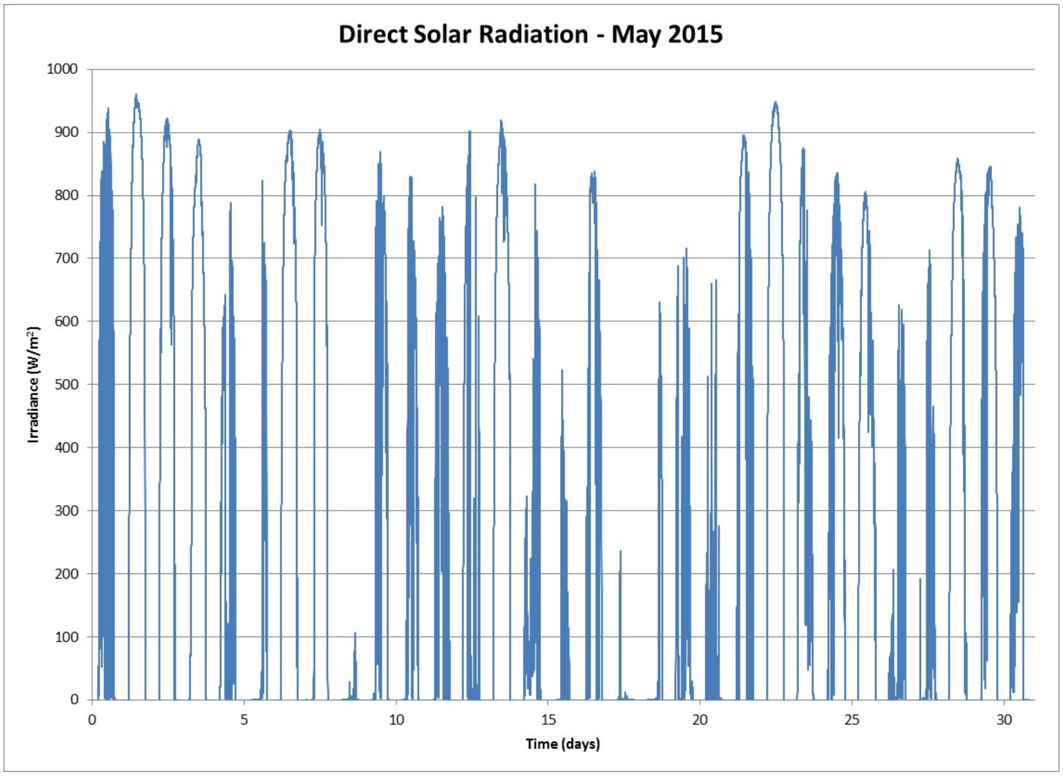

Figure 154 Direct Solar Radiation for the Month May 2015

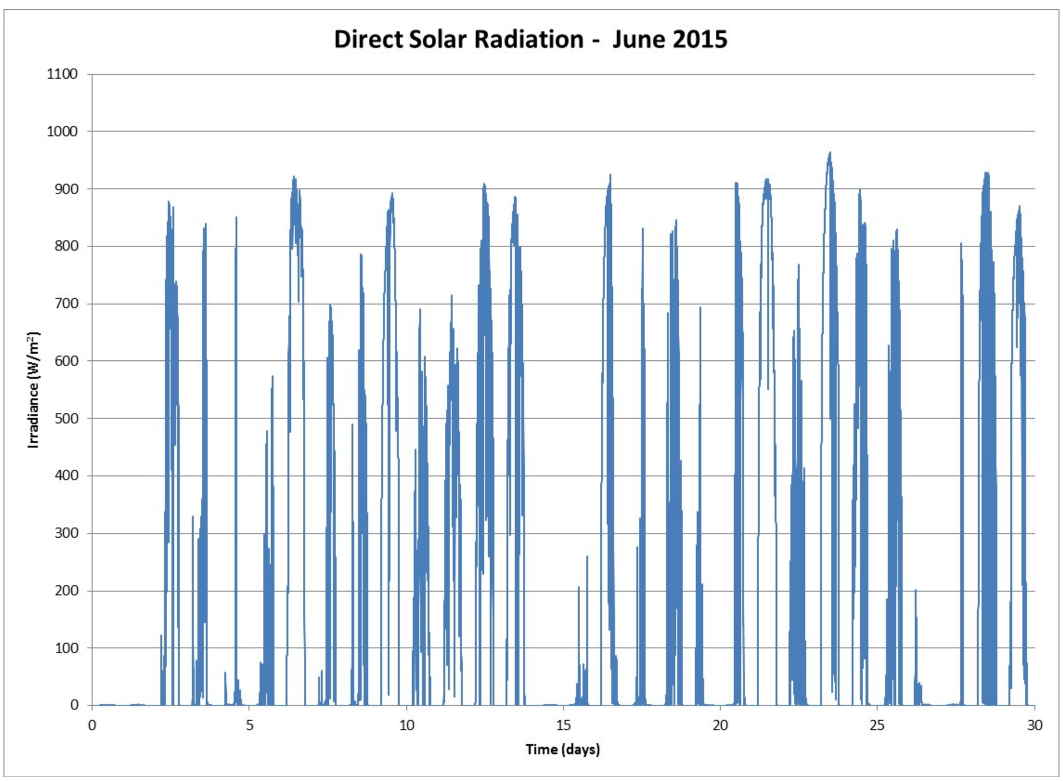

Figure 155 Direct Solar Radiation for the Month June 2015

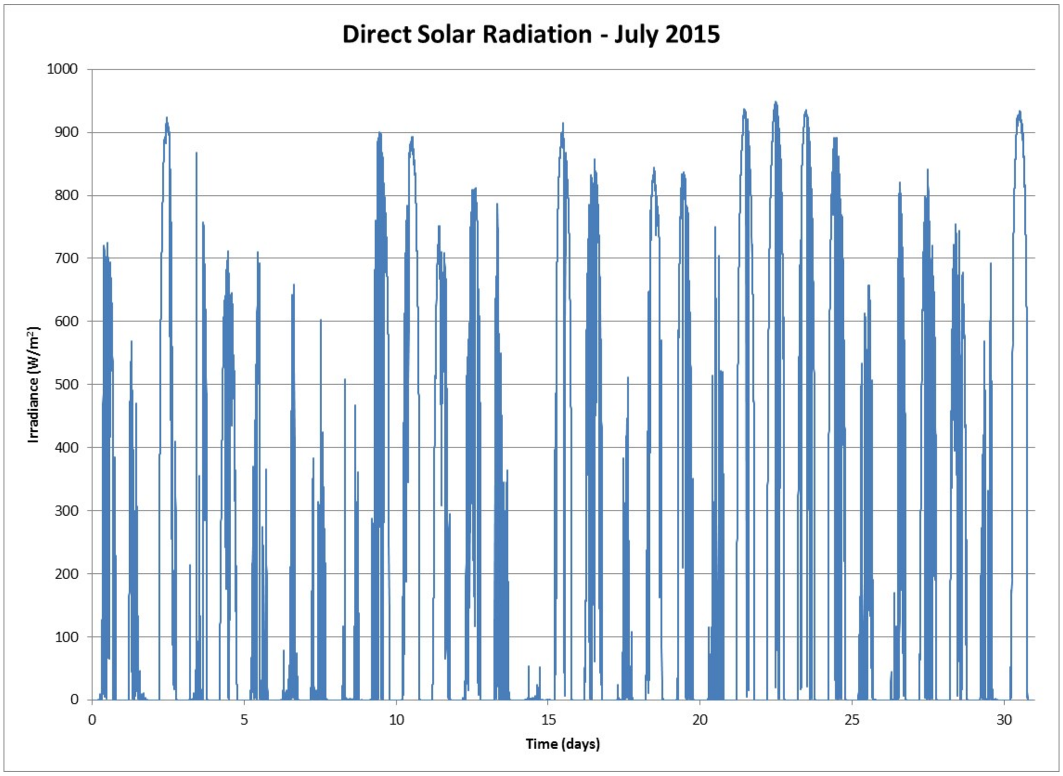

Figure 156 Direct Solar Radiation for the Month July 2015

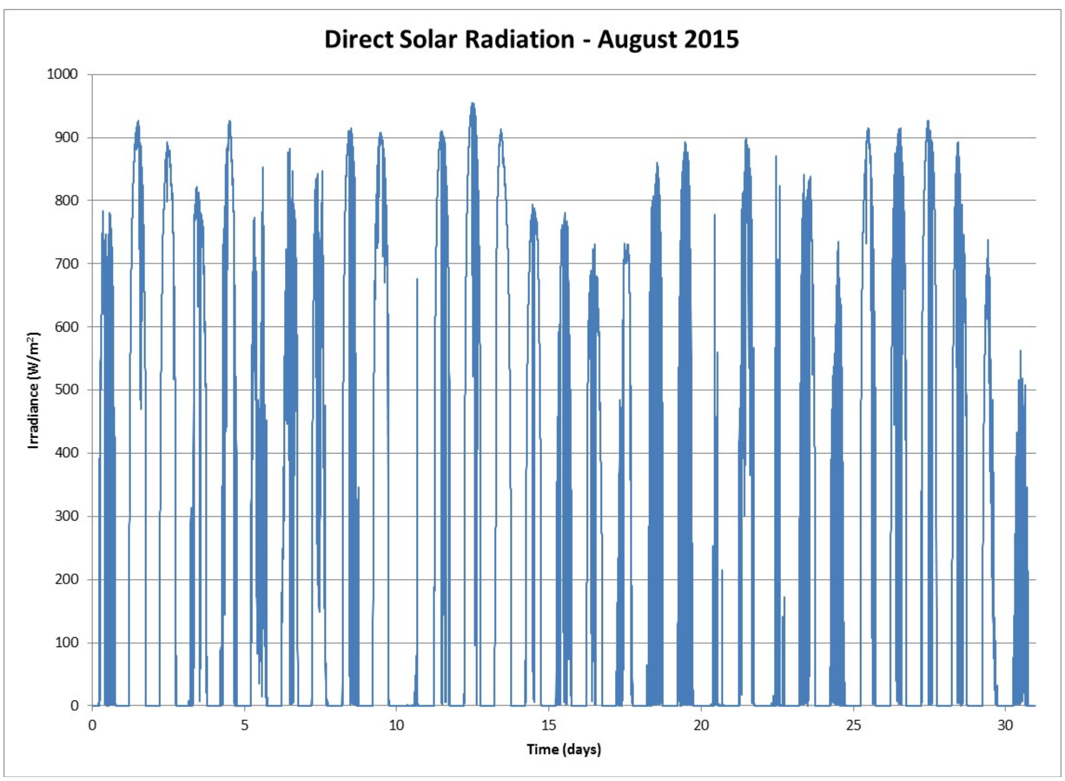

Figure 157 Direct Solar Radiation for the Month August 2015

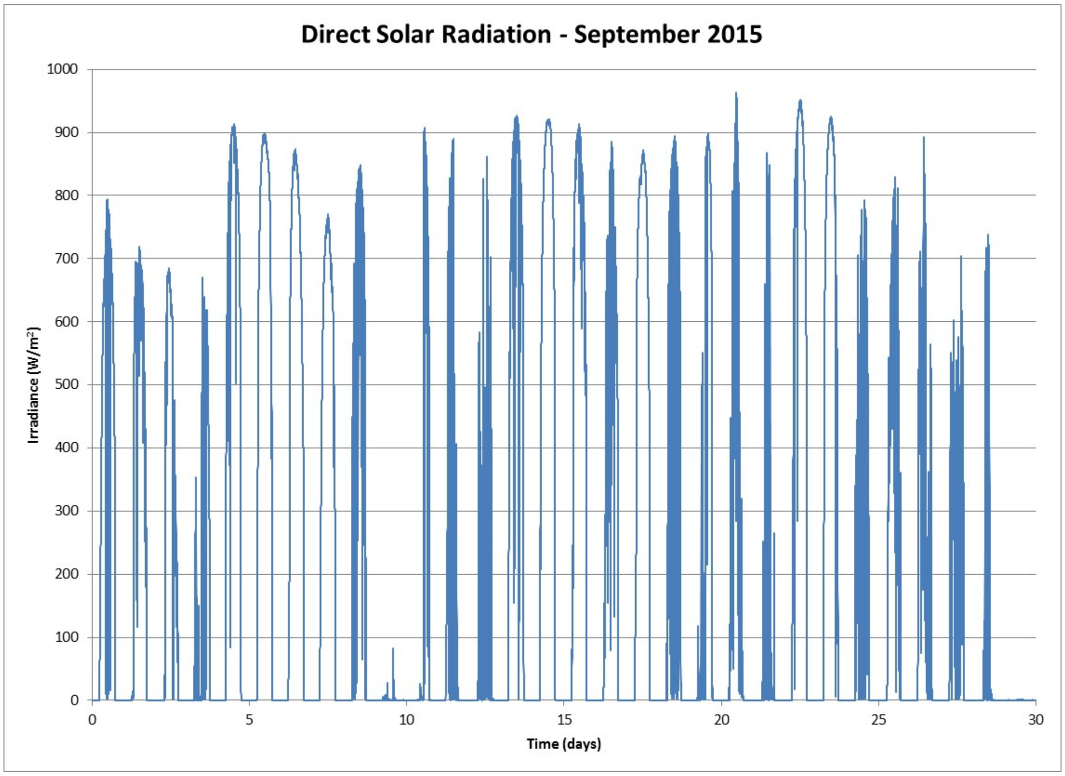

Figure 158 Direct Solar Radiation for the Month September 2015

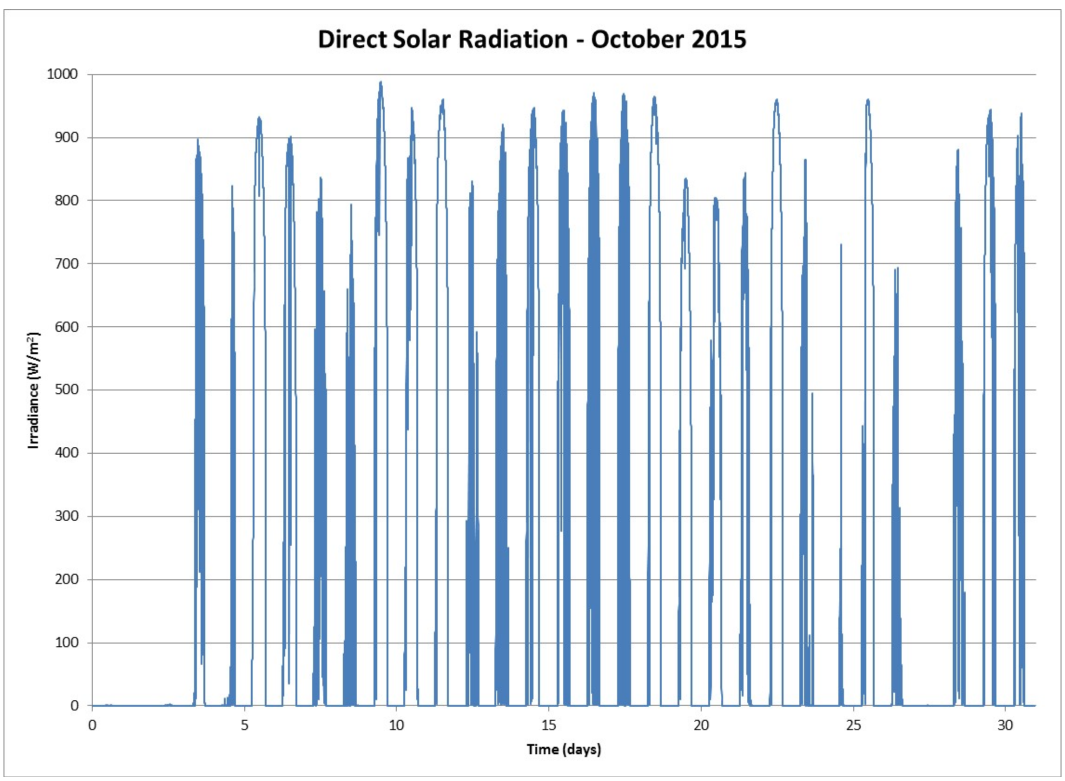

Figure 159 Direct Solar Radiation for the Month October 2015

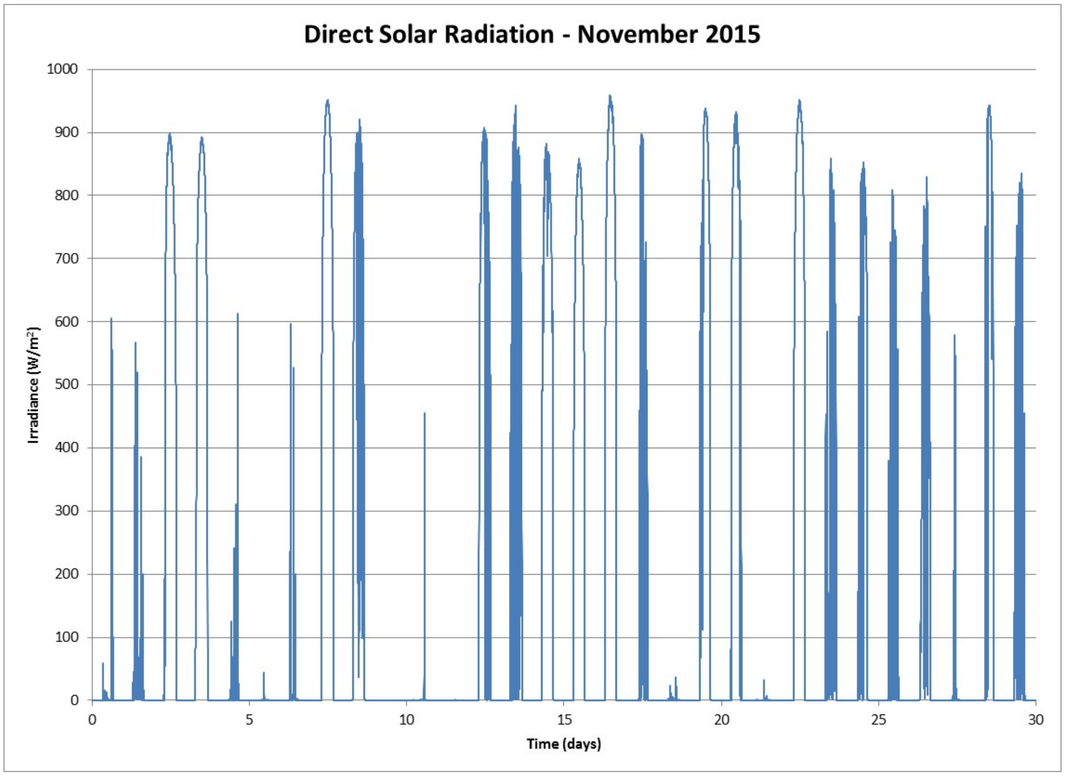

Figure 160 Direct Solar Radiation for the Month November 2015

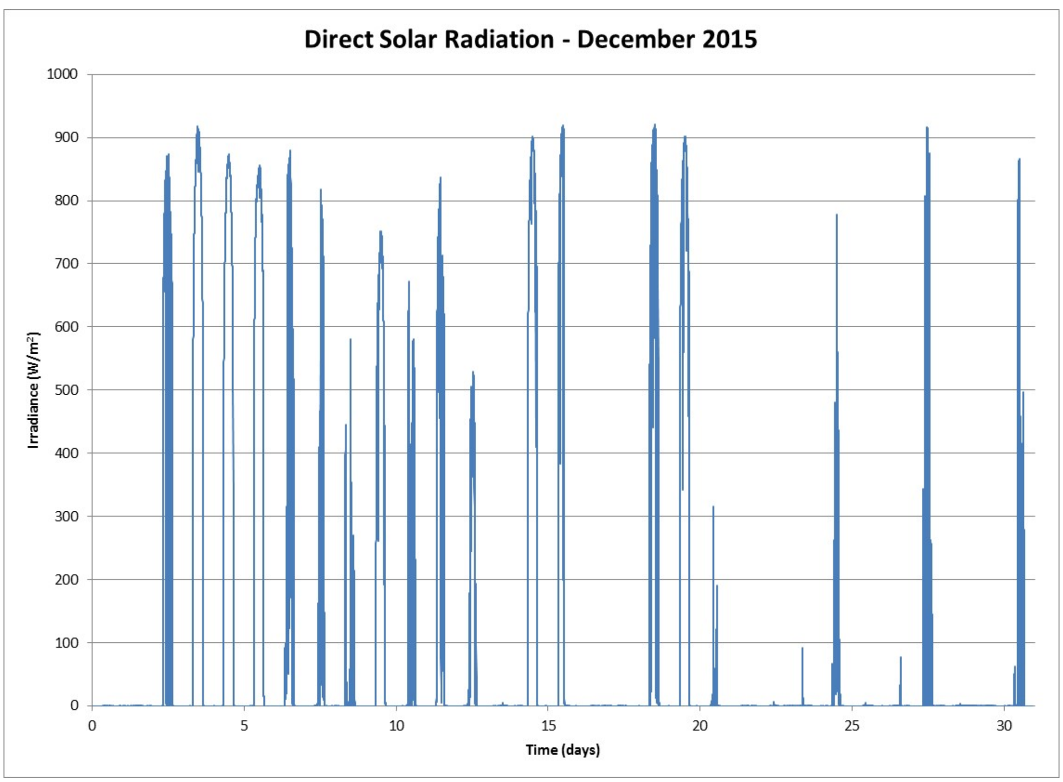

Figure 161 Direct Solar Radiation for the Month December 2015

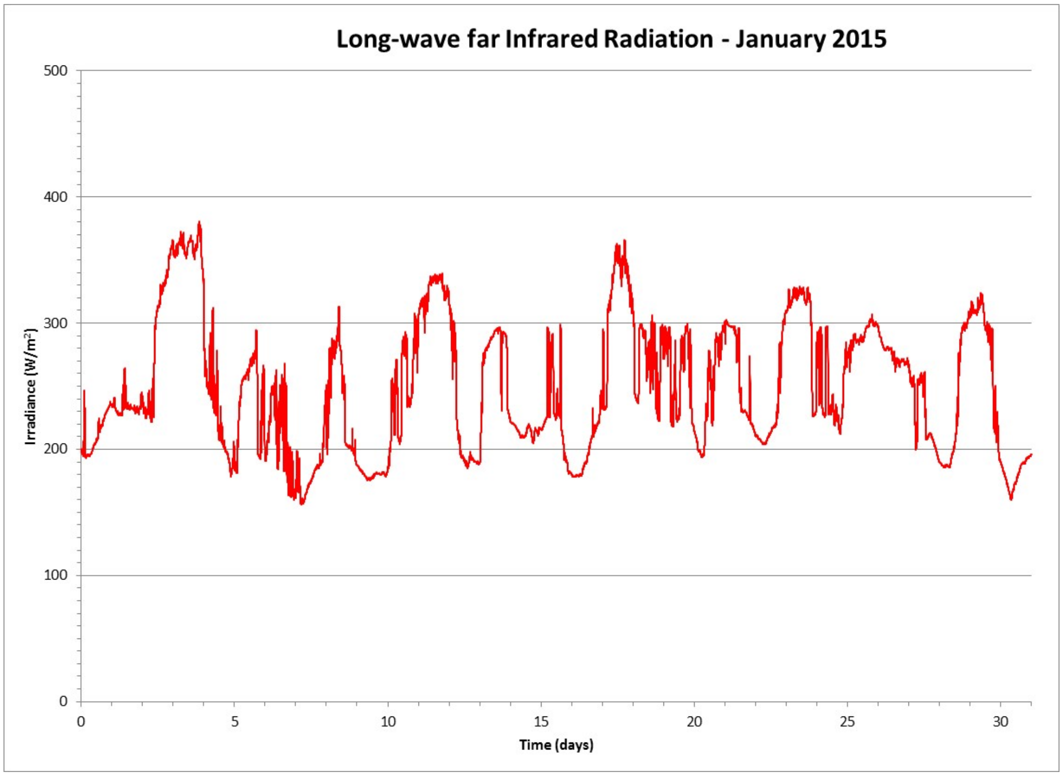

Figure 162 Long-wave Far Infrared Radiation for the Month of January 2015

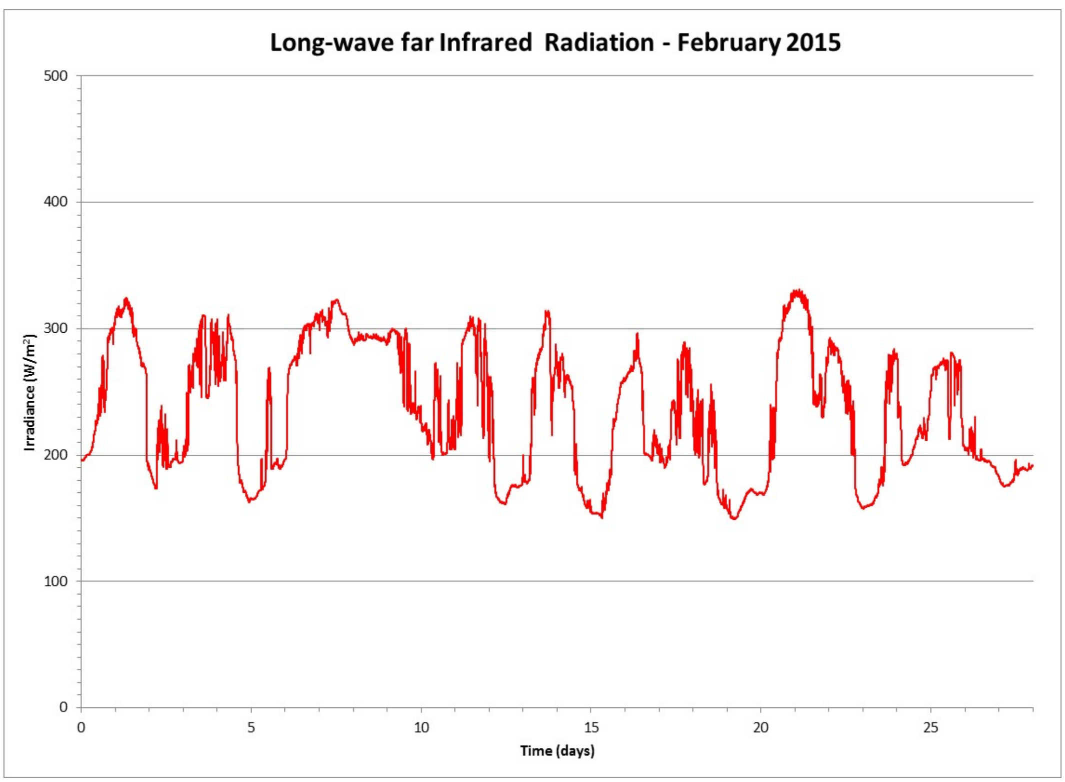

Figure 163 Long-wave Far Infrared Radiation for the Month of February 2015

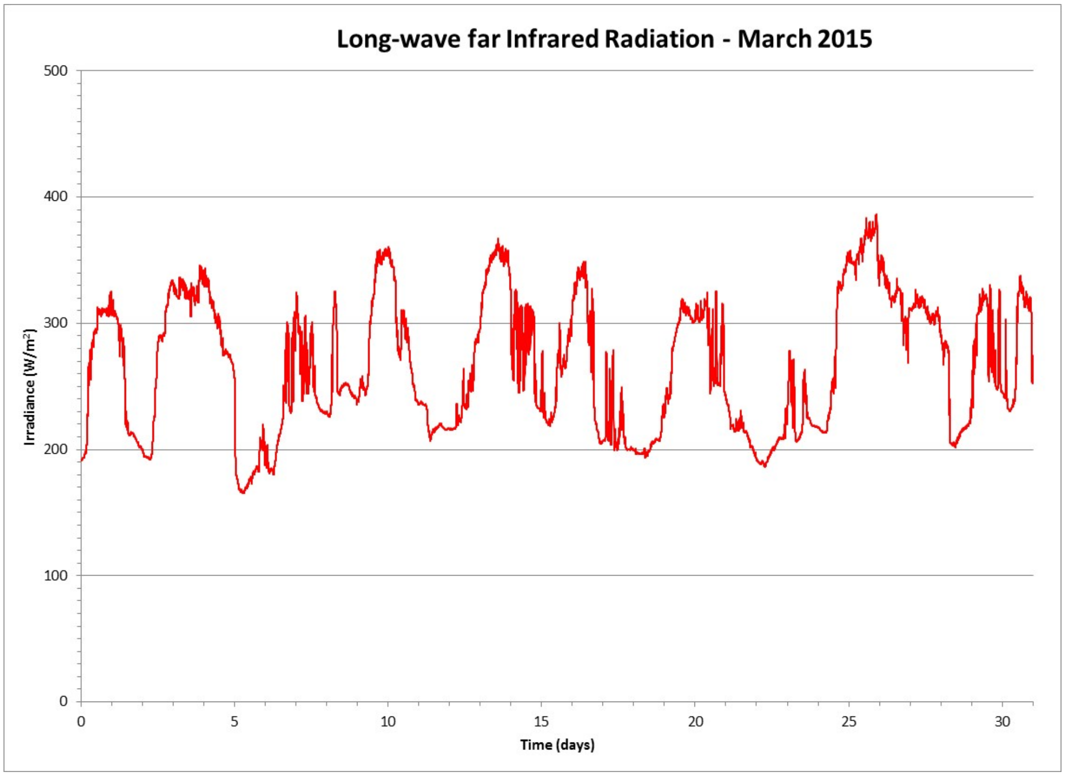

Figure 164 Long-wave Far Infrared Radiation for the Month of March 2015

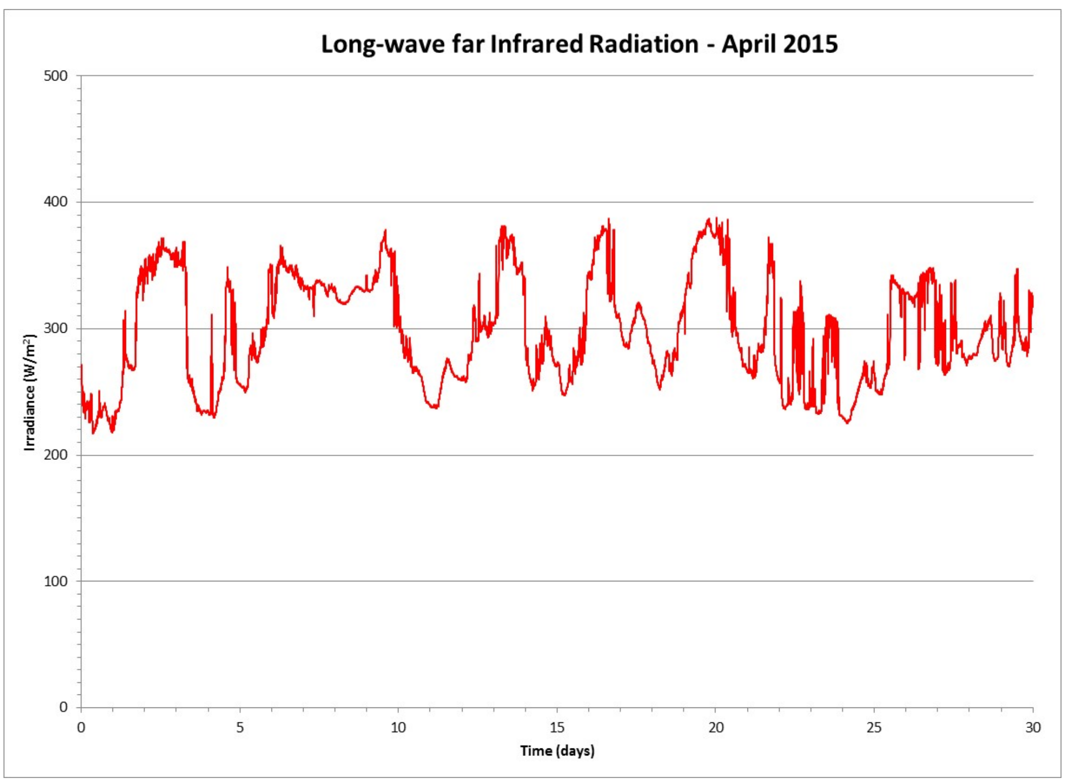

Figure 165 Long-wave Far Infrared Radiation for the Month of April 2015

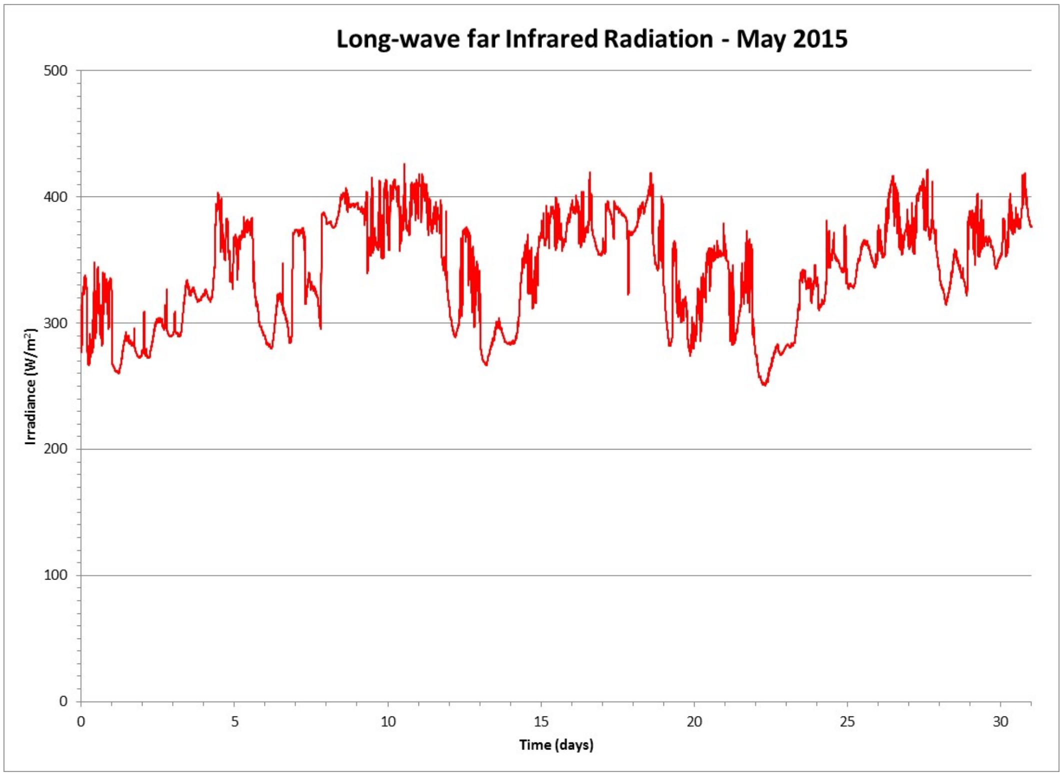

Figure 166 Long-wave Far Infrared Radiation for the Month of May 2015

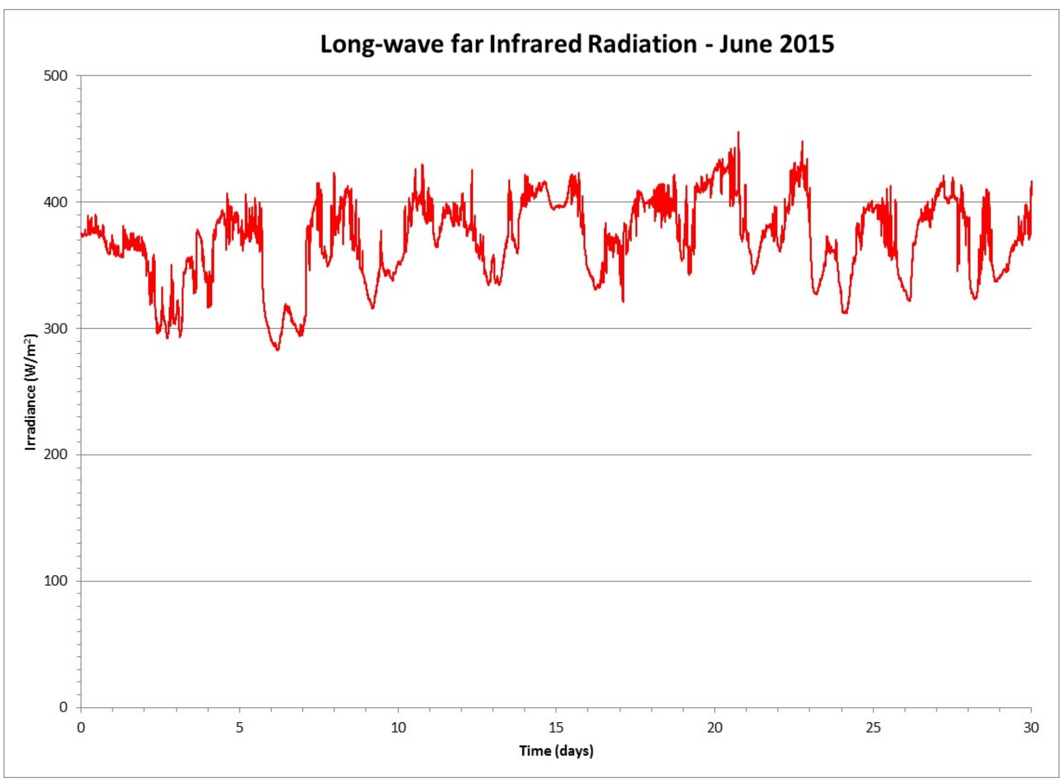

Figure 167 Long-wave Far Infrared Radiation for the Month of June 2015

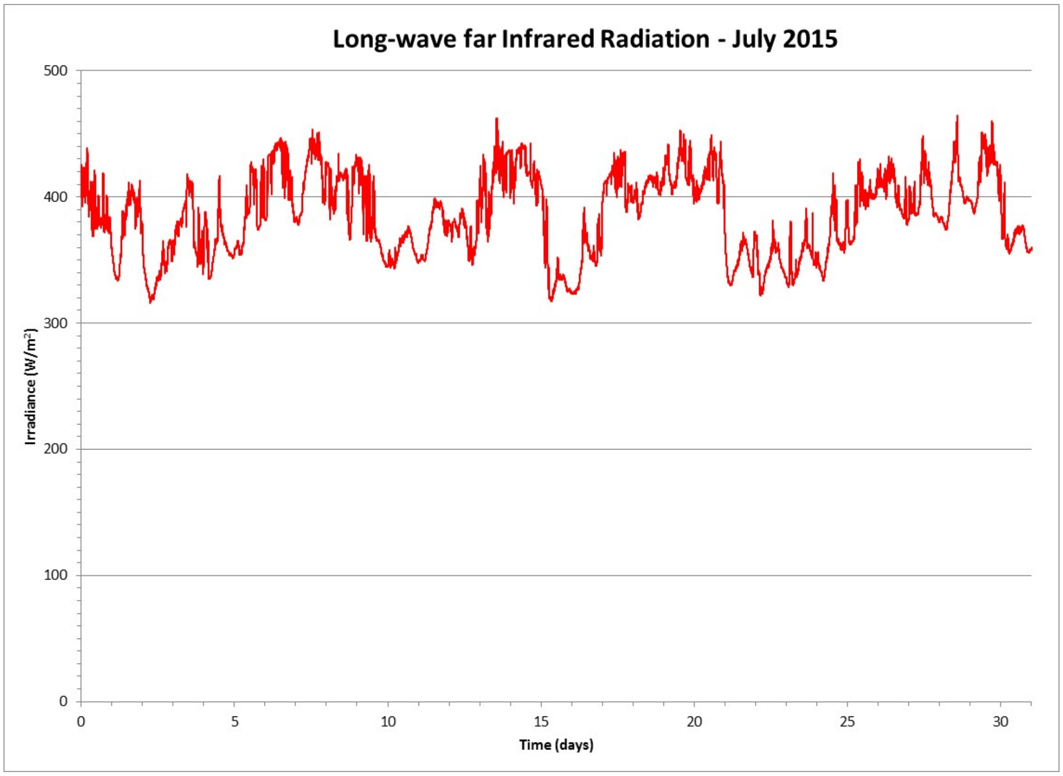

Figure 168 Long-wave Far Infrared Radiation for the Month of July 2015

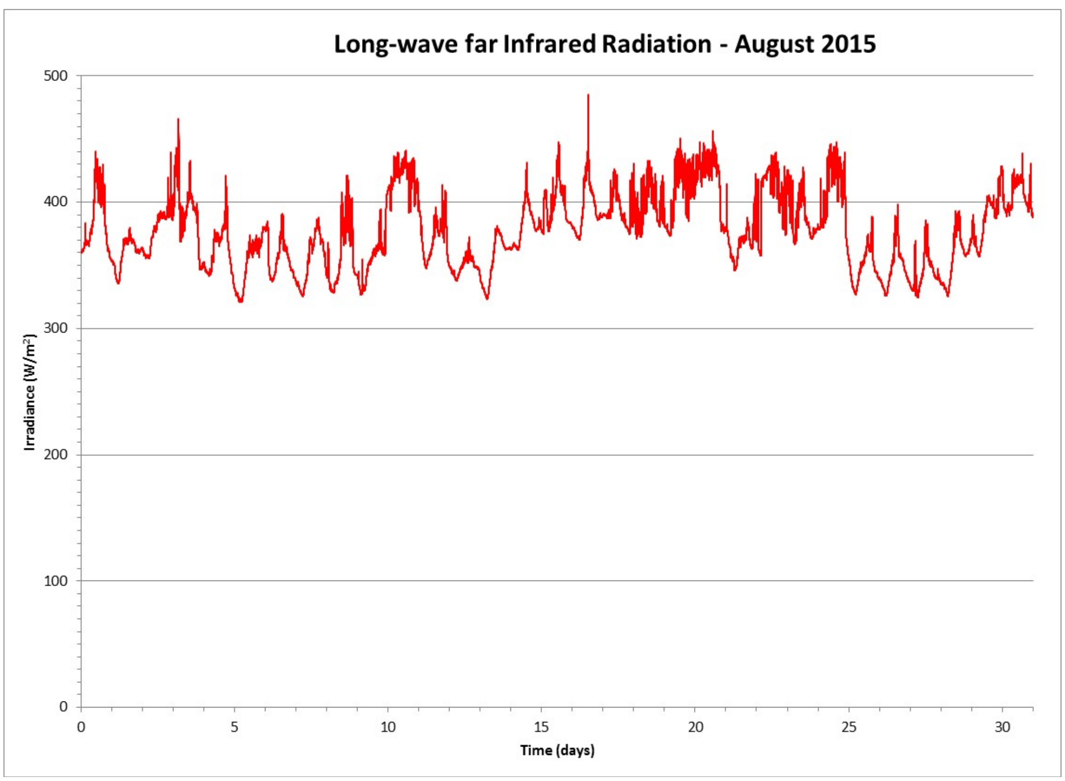

Figure 169 Long-wave Far Infrared Radiation for the Month of August 2015

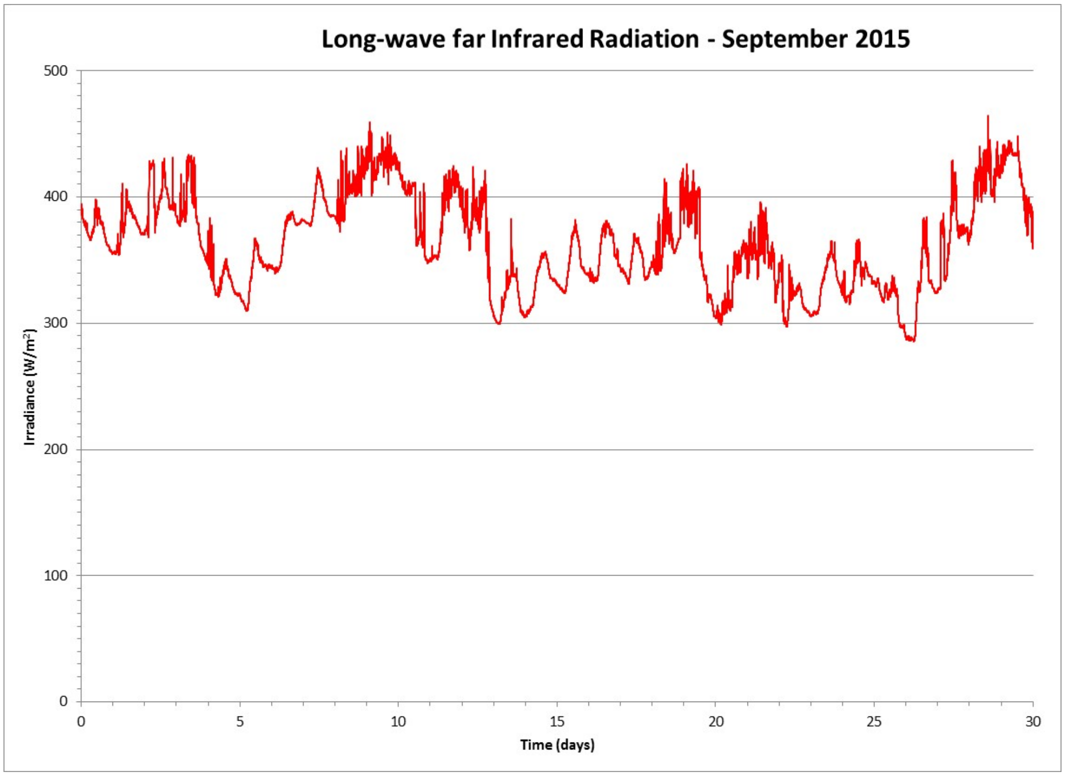

Figure 170 Long-wave Far Infrared Radiation for the Month of September 2015

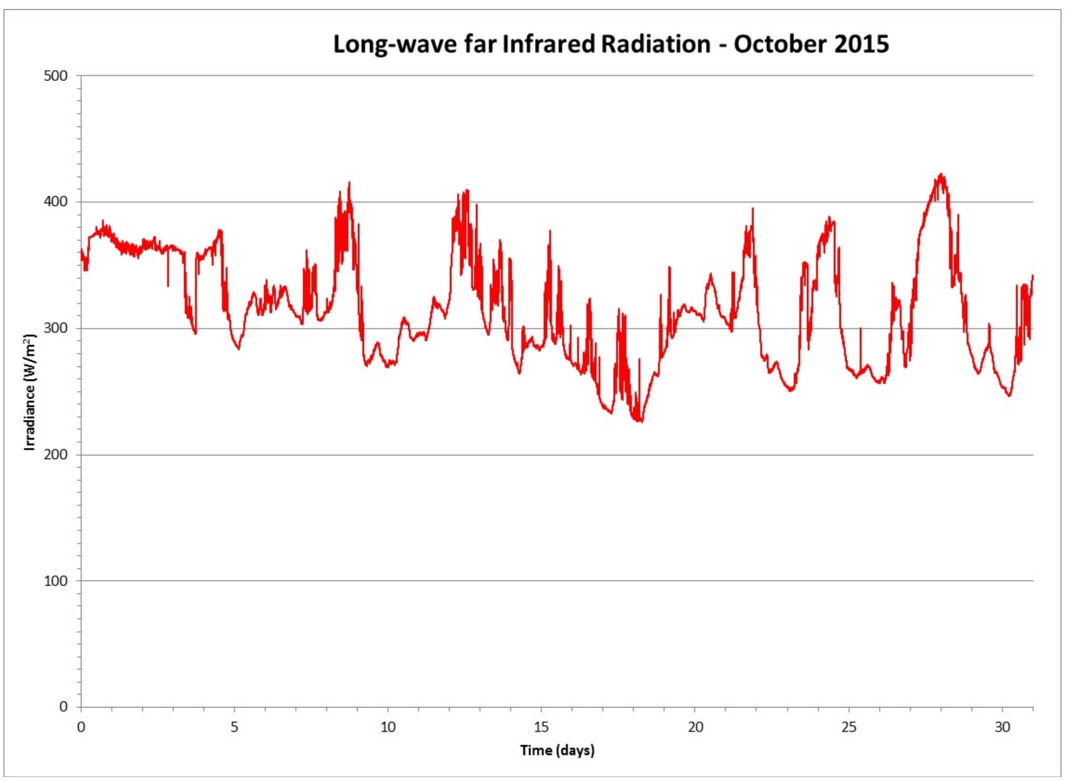

Figure 171 Long-wave Far Infrared Radiation for the Month of October 2015

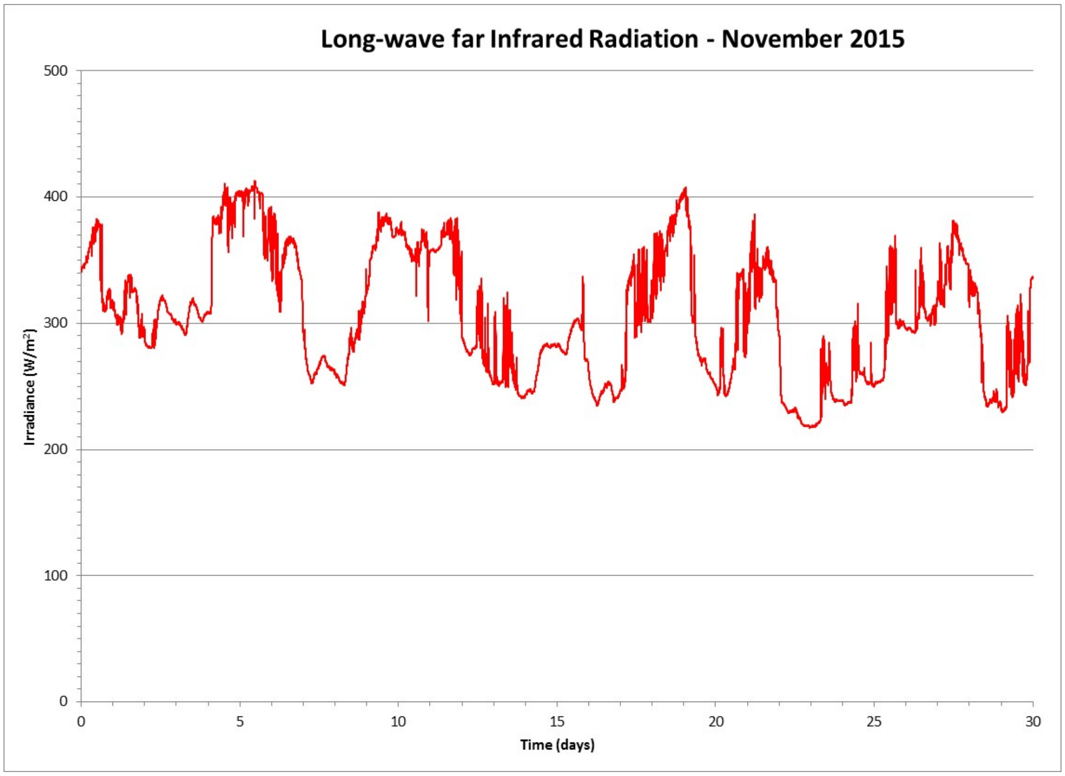

Figure 172 Long-wave Far Infrared Radiation for the Month of November 2015

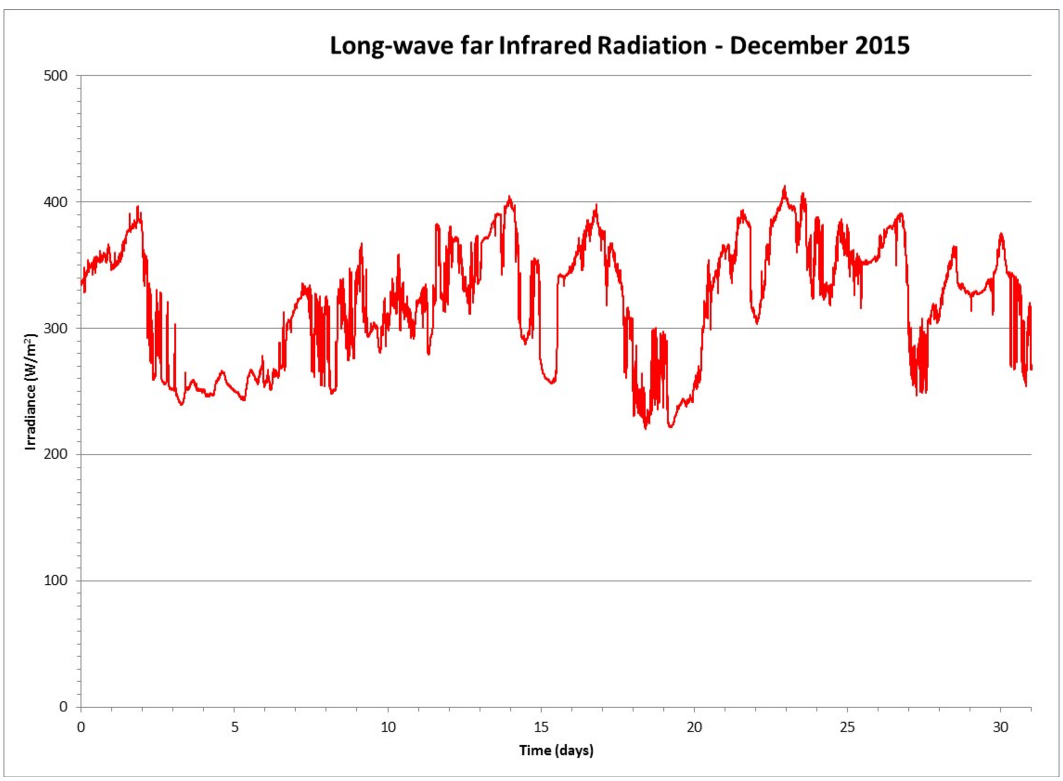

Figure 173 Long-wave Far Infrared Radiation for the Month of December 2015

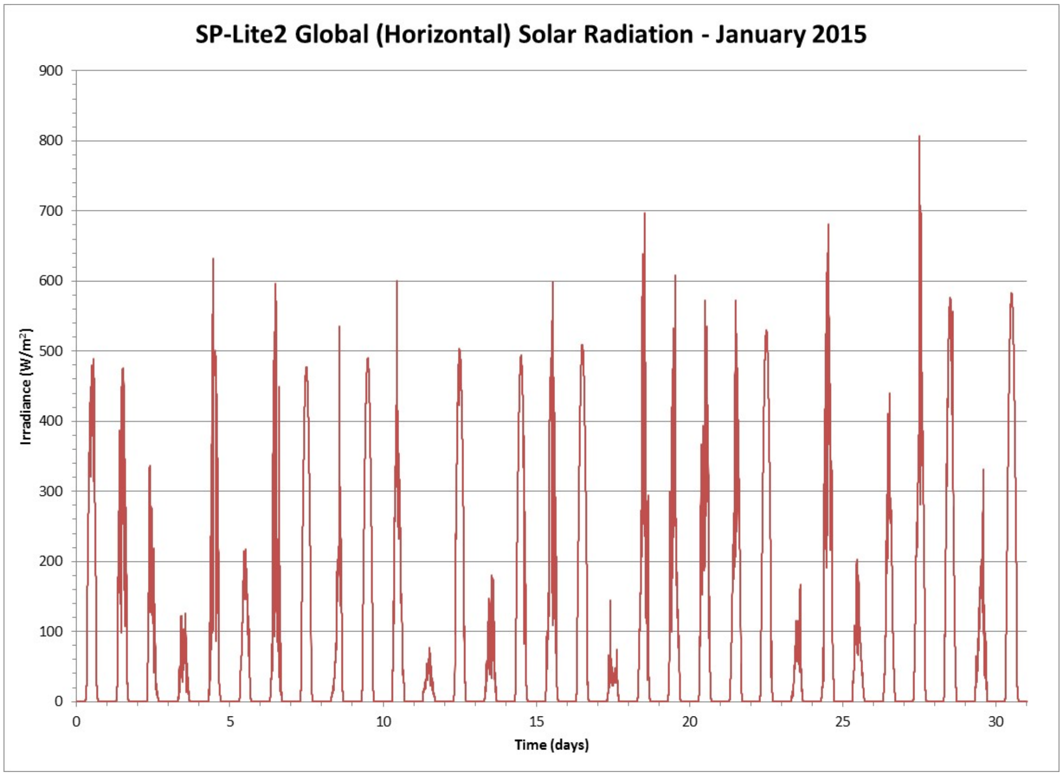

Figure 174 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of January 2015

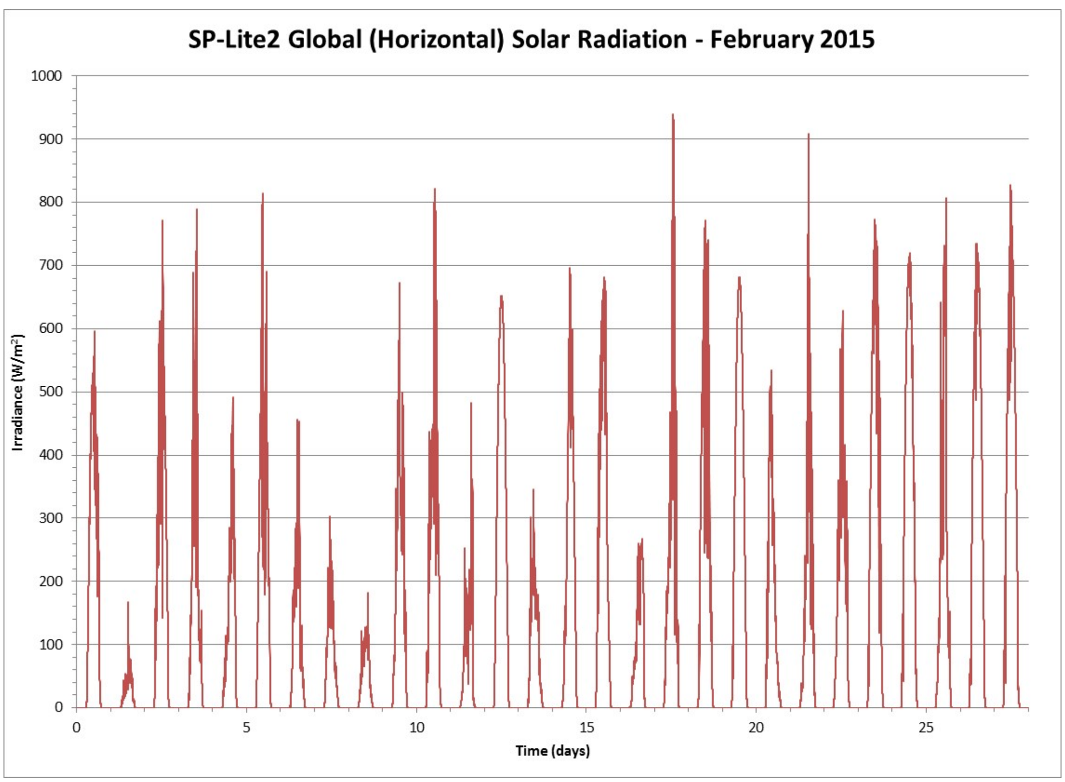

Figure 175 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of February 2015

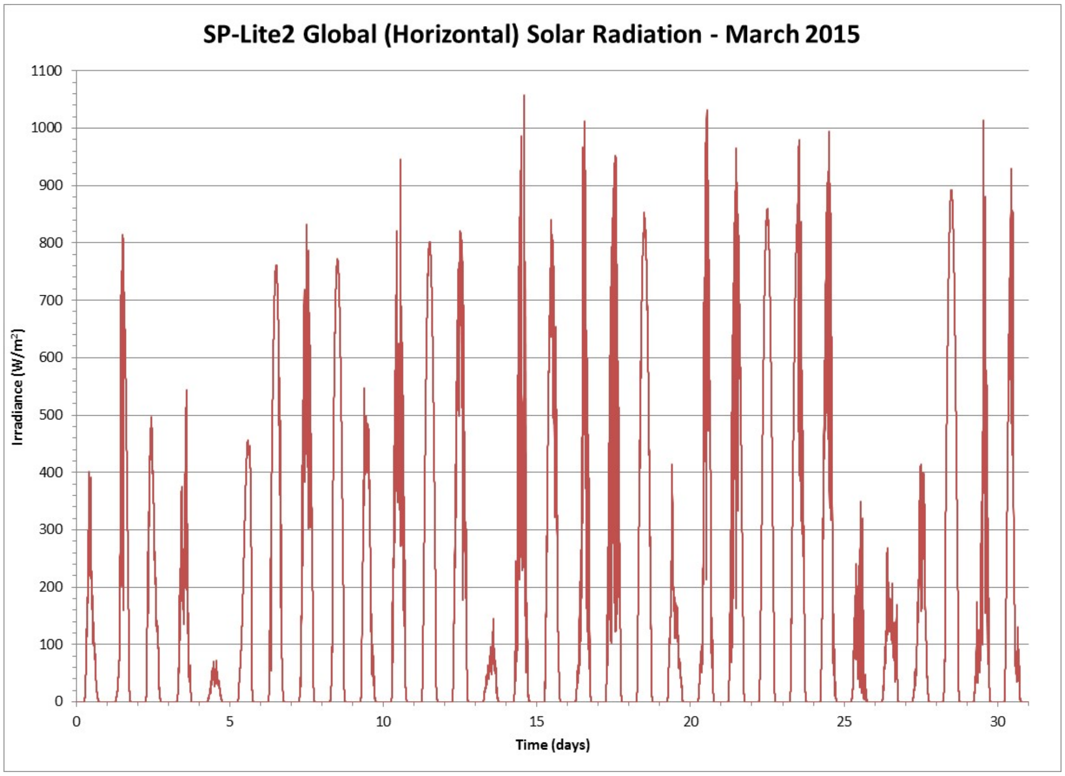

Figure 176 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of March 2015

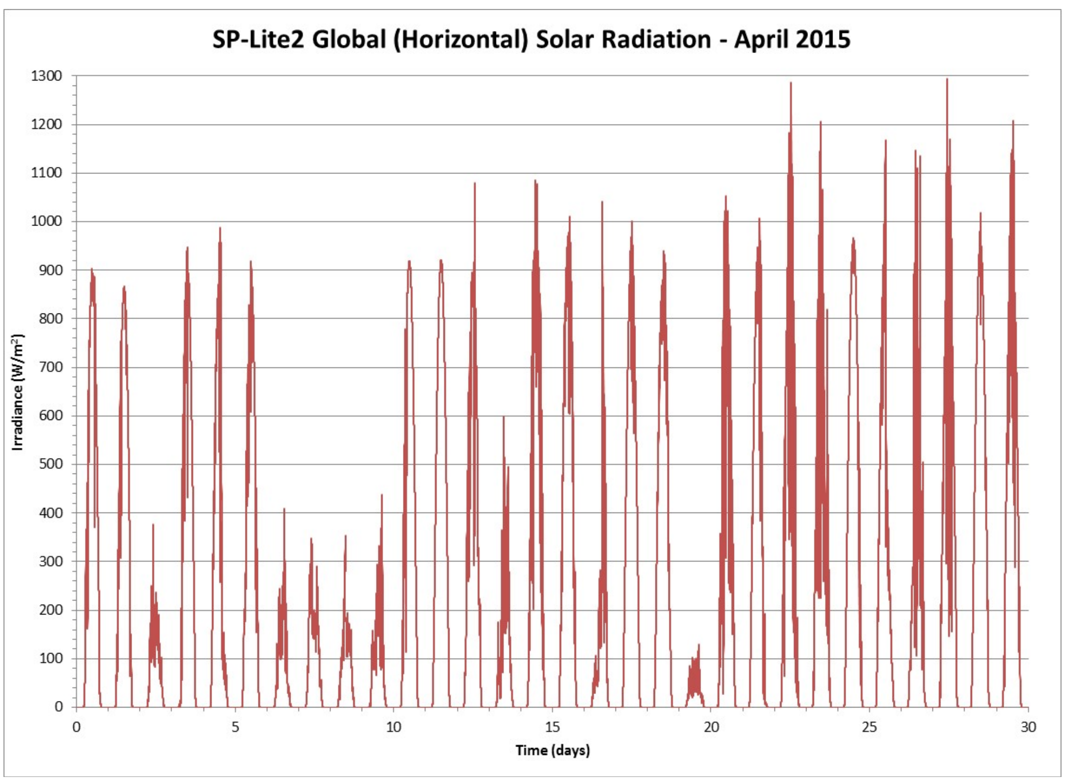

Figure 177 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of April 2015

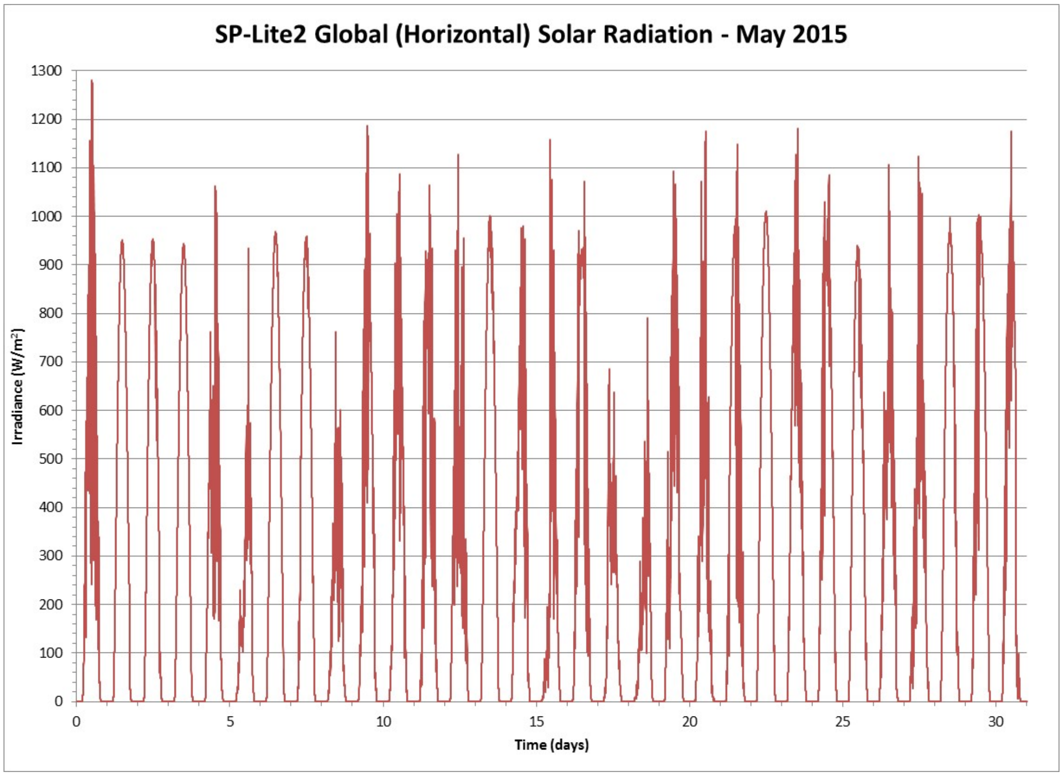

Figure 178 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of May 2015

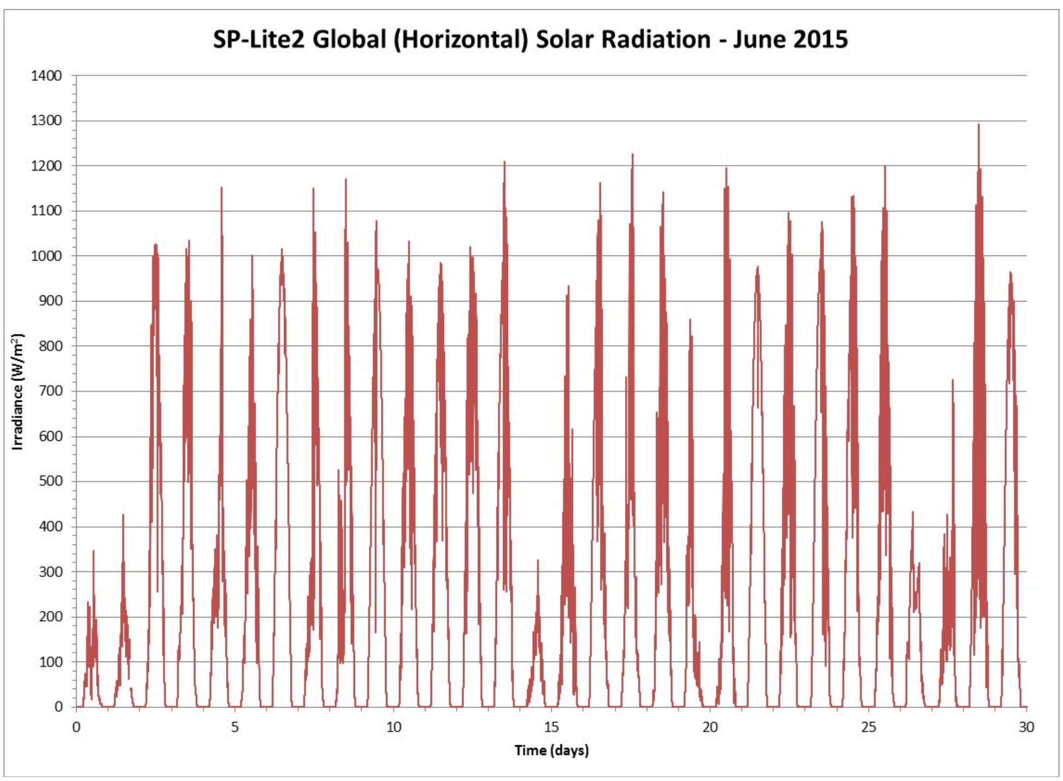

Figure 179 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of June 2015

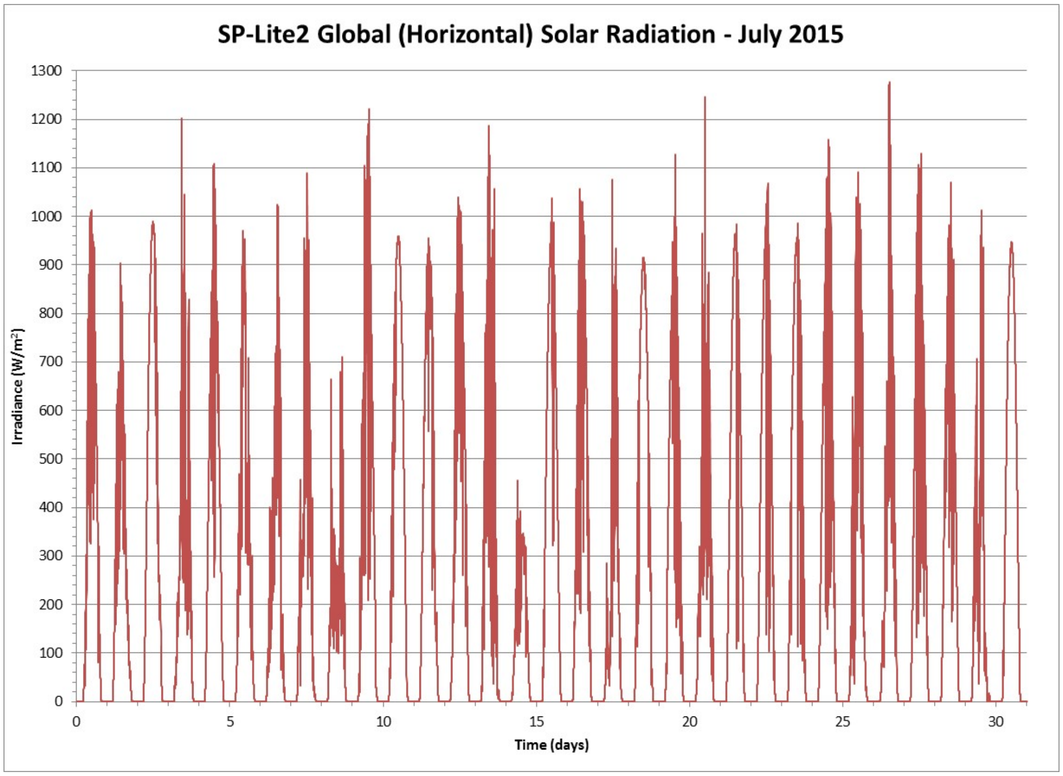

Figure 180 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of July 2015

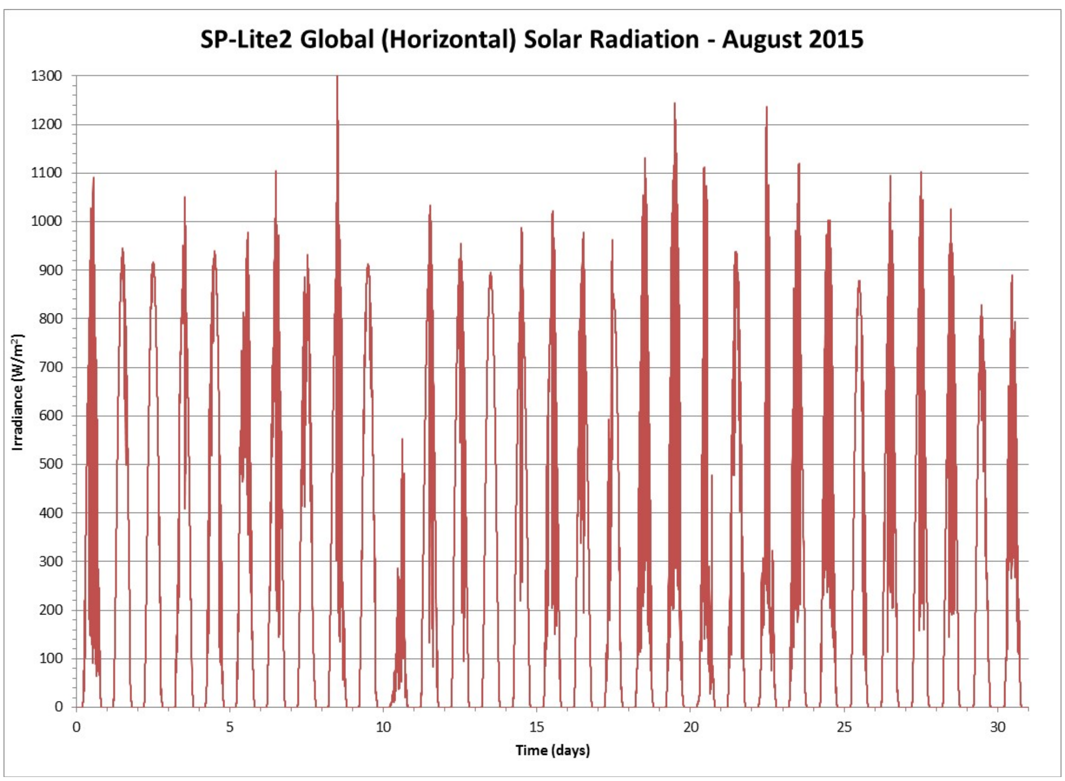

Figure 181 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of August 2015

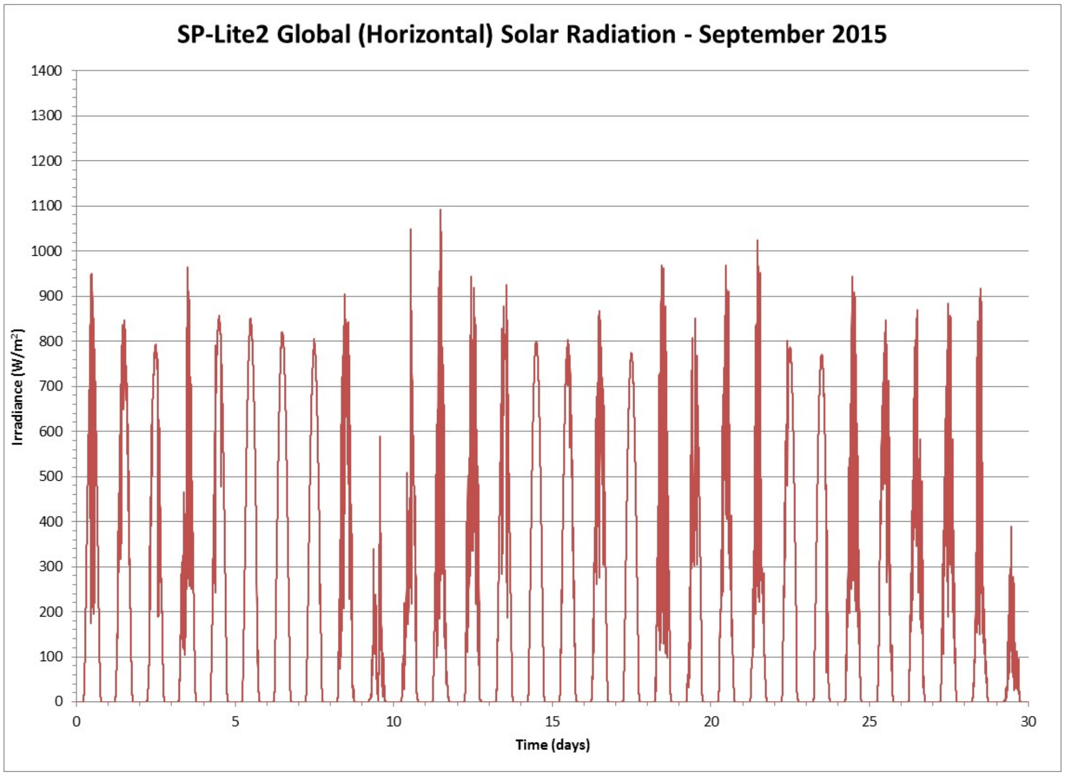

Figure 182 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of September 2015

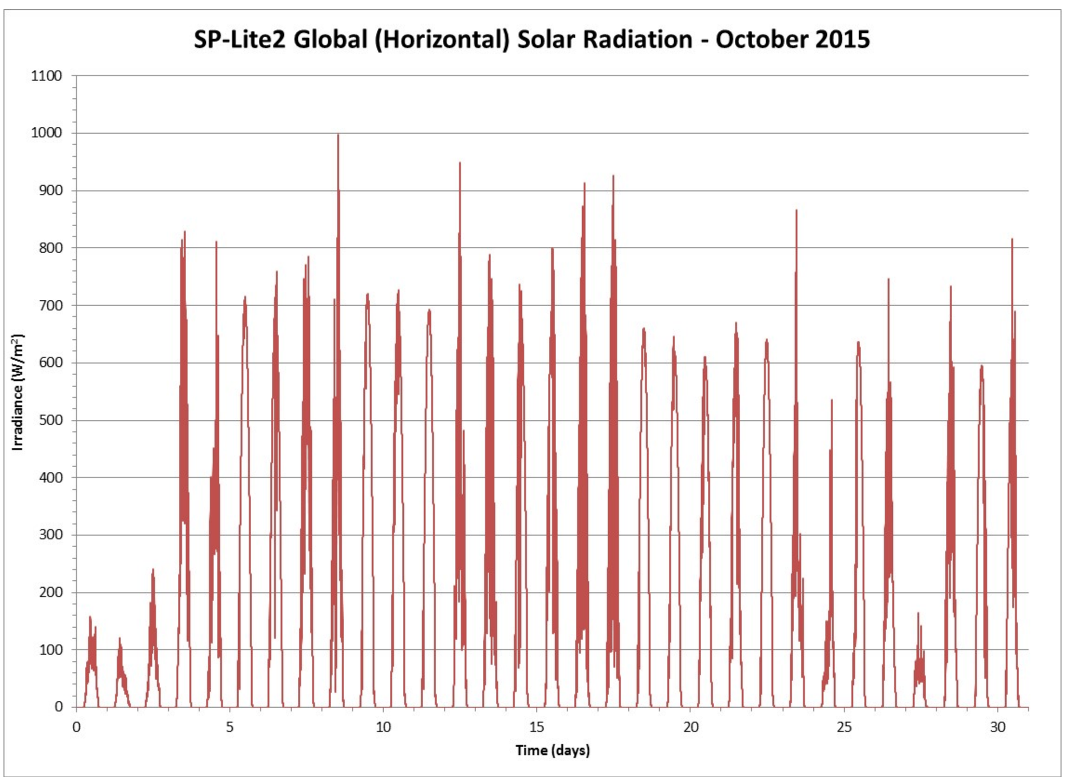

Figure 183 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of October 2015

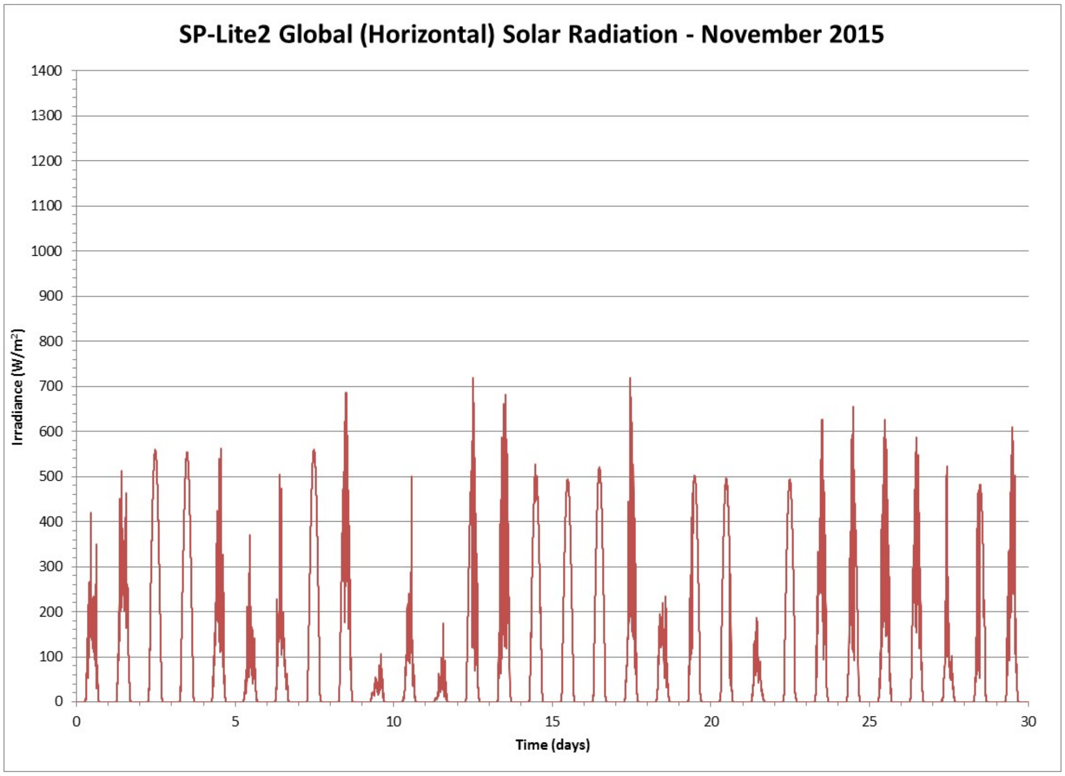

Figure 184 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of November 2015

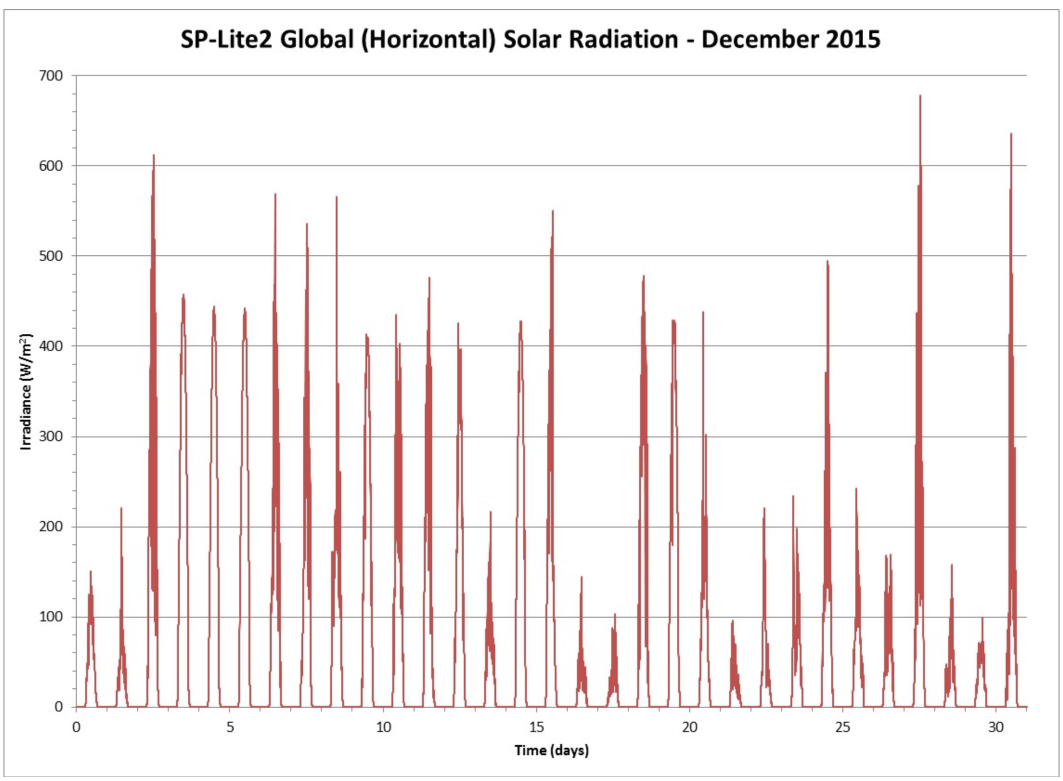

Figure 185 Global Solar Radiation from an SP-Lite2 Pyranometer for the Month of December 2015

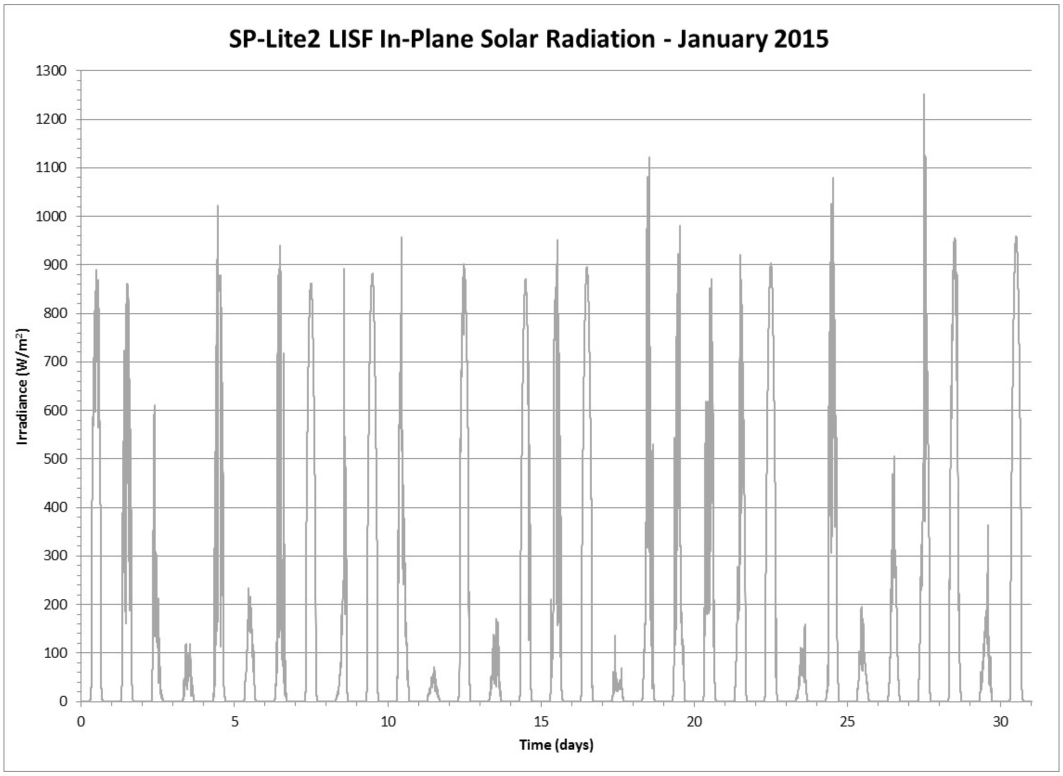

Figure 186 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for January 2015

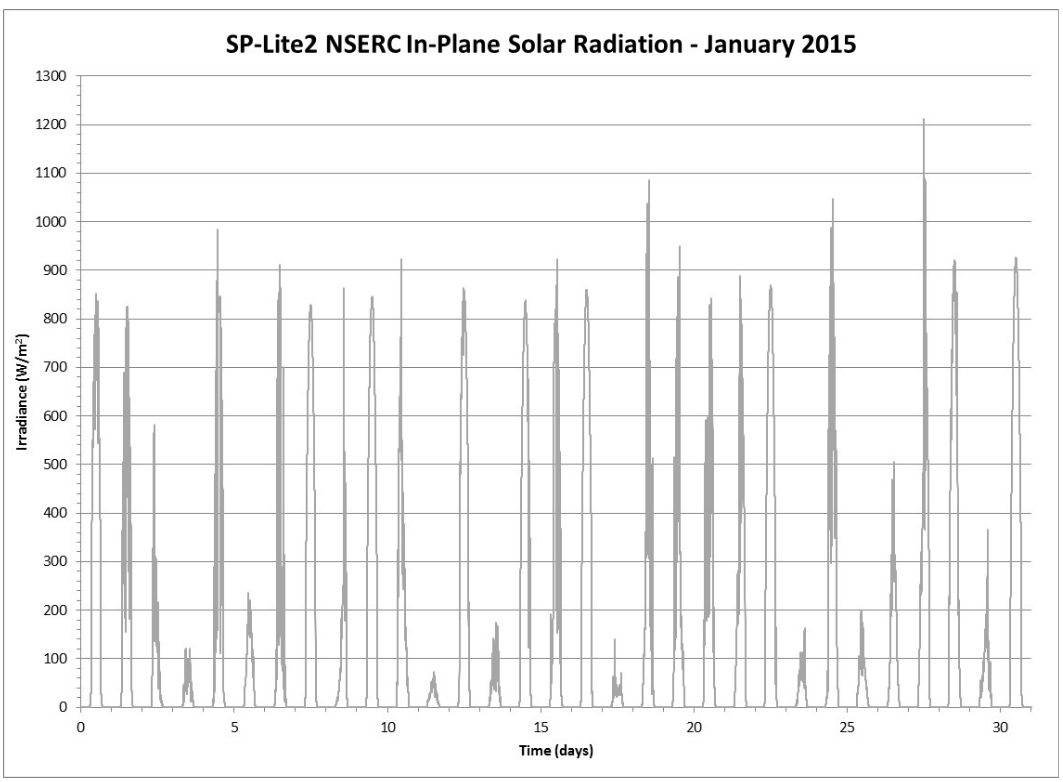

Figure 187 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for January 2015

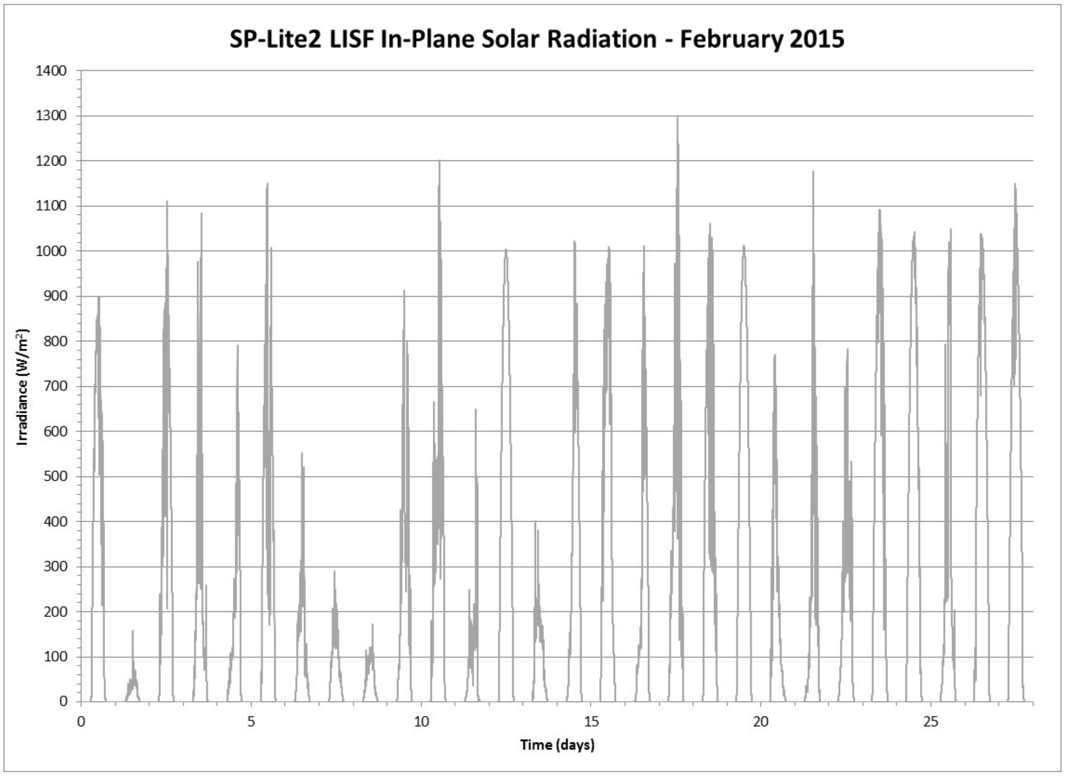

Figure 188 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for February 2015

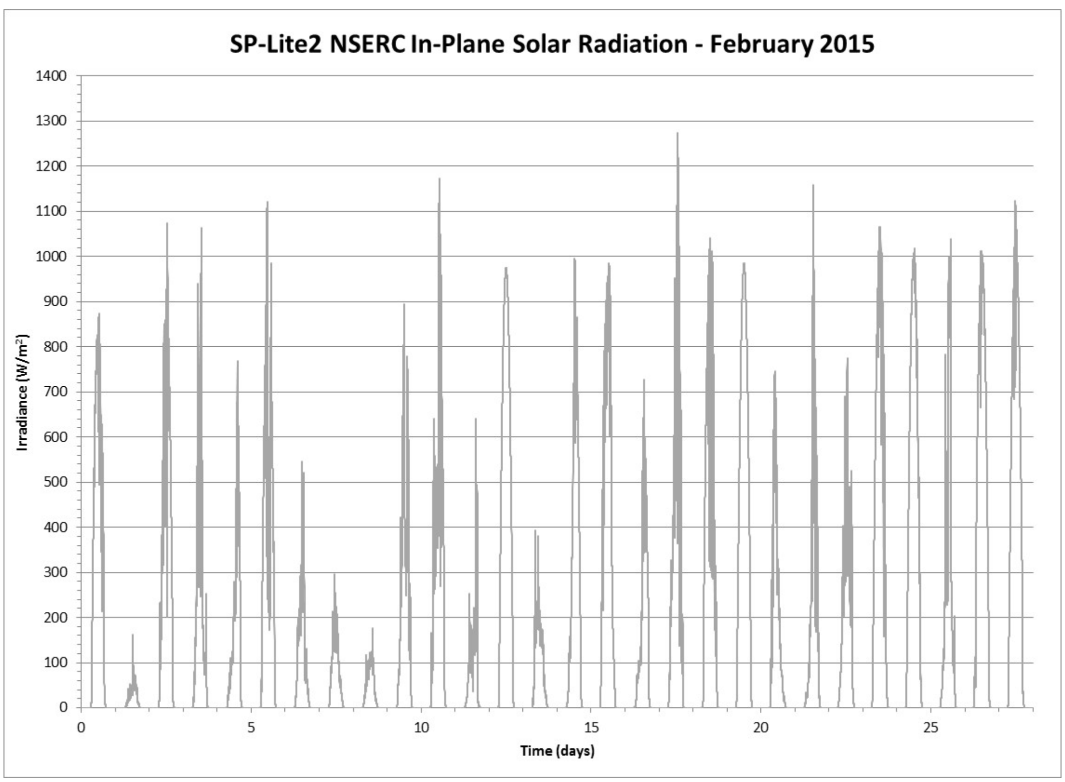

Figure 189 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for February 2015

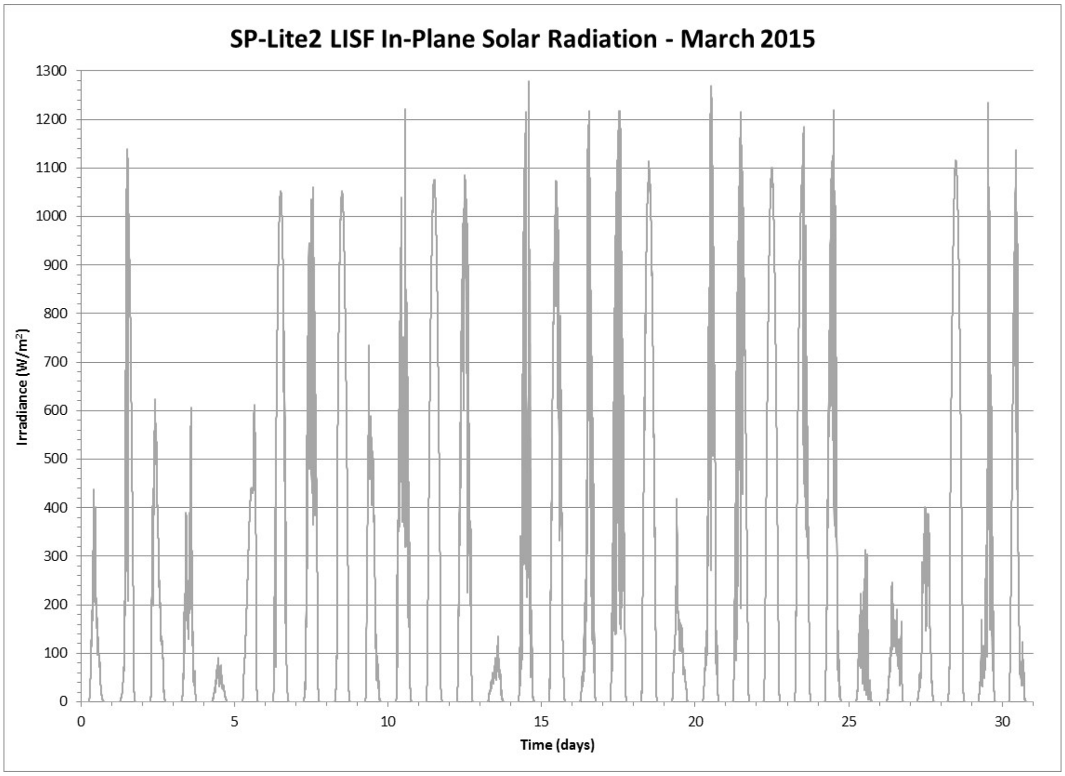

Figure 190 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for March 2015

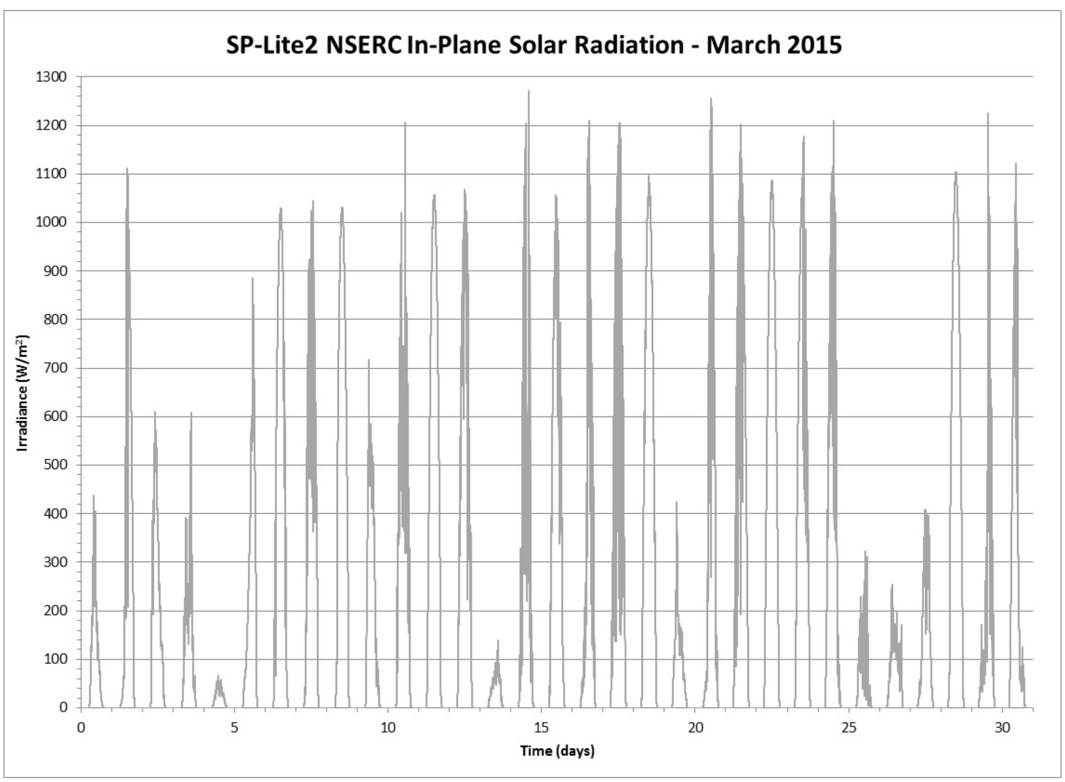

Figure 191 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for March 2015

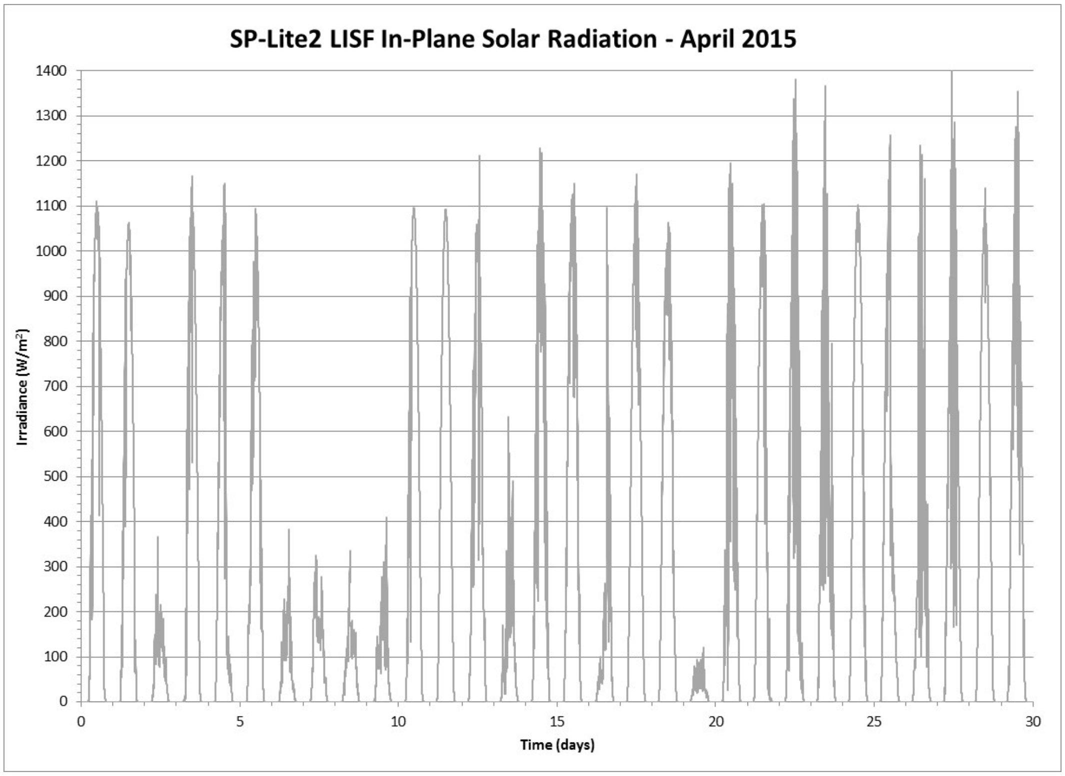

Figure 192 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for April 2015

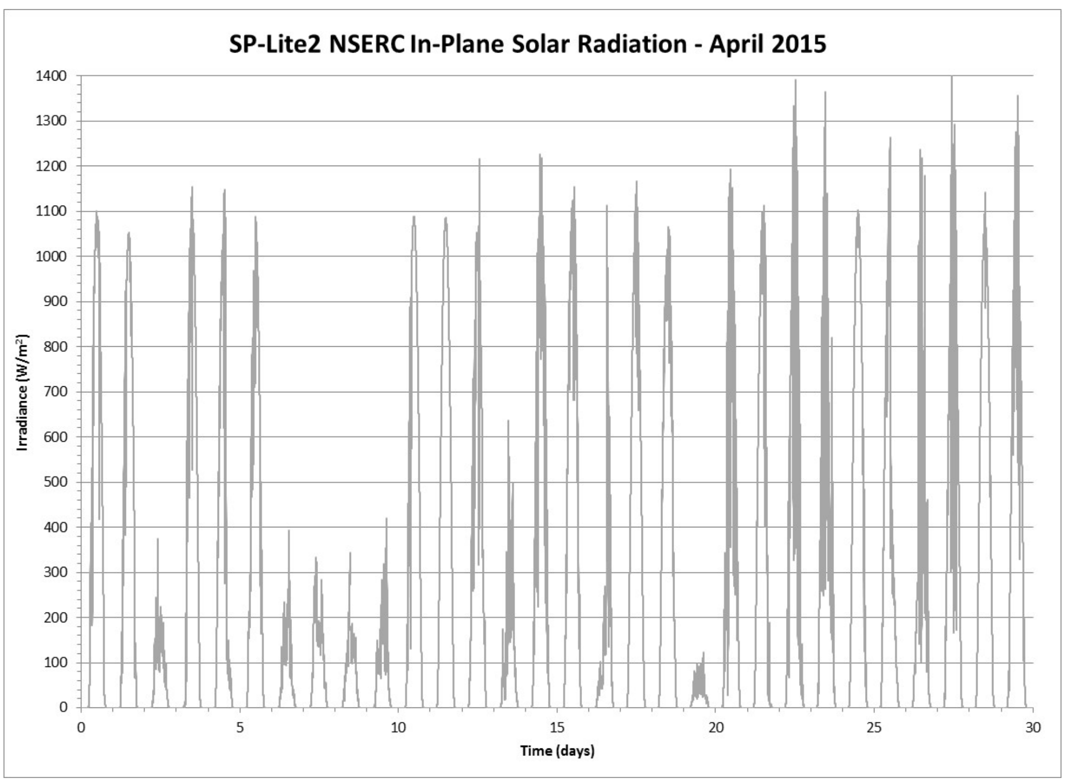

Figure 193 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for April 2015

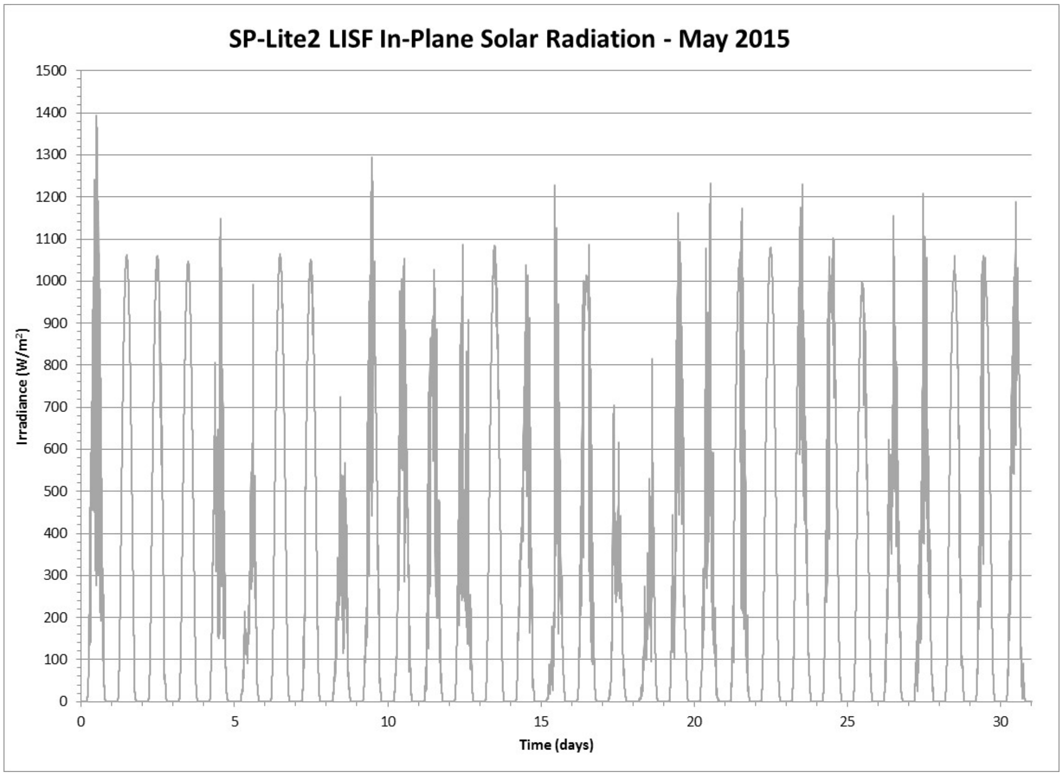

Figure 194 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for May 2015

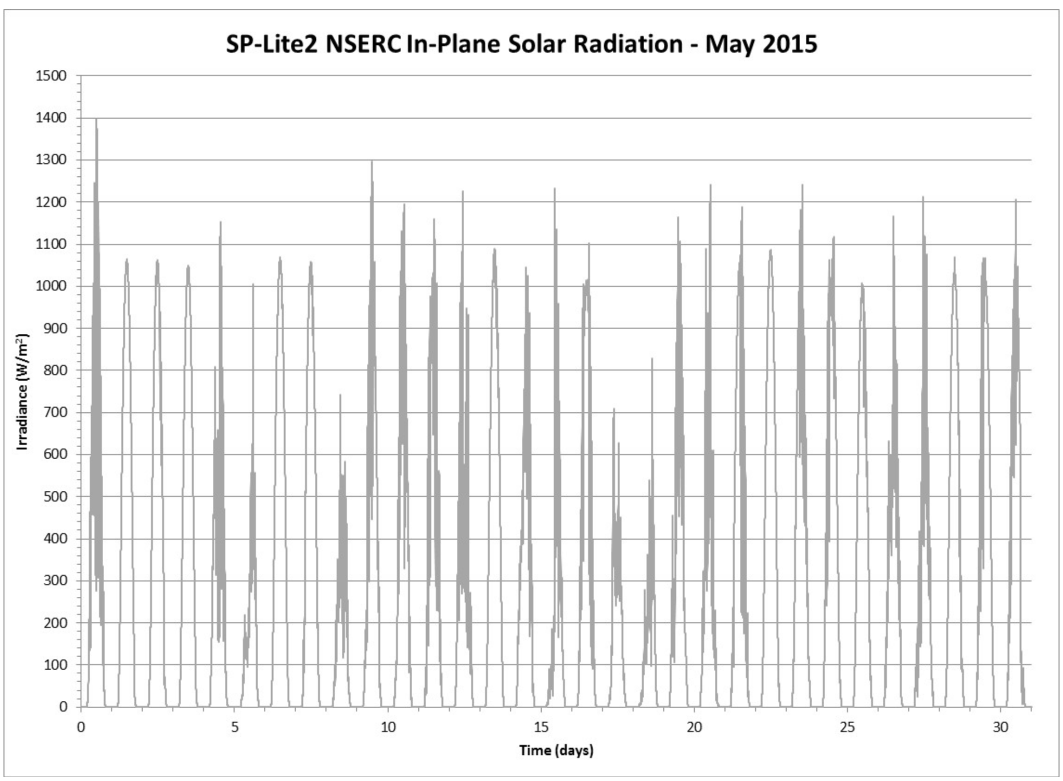

Figure 195 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for May 2015

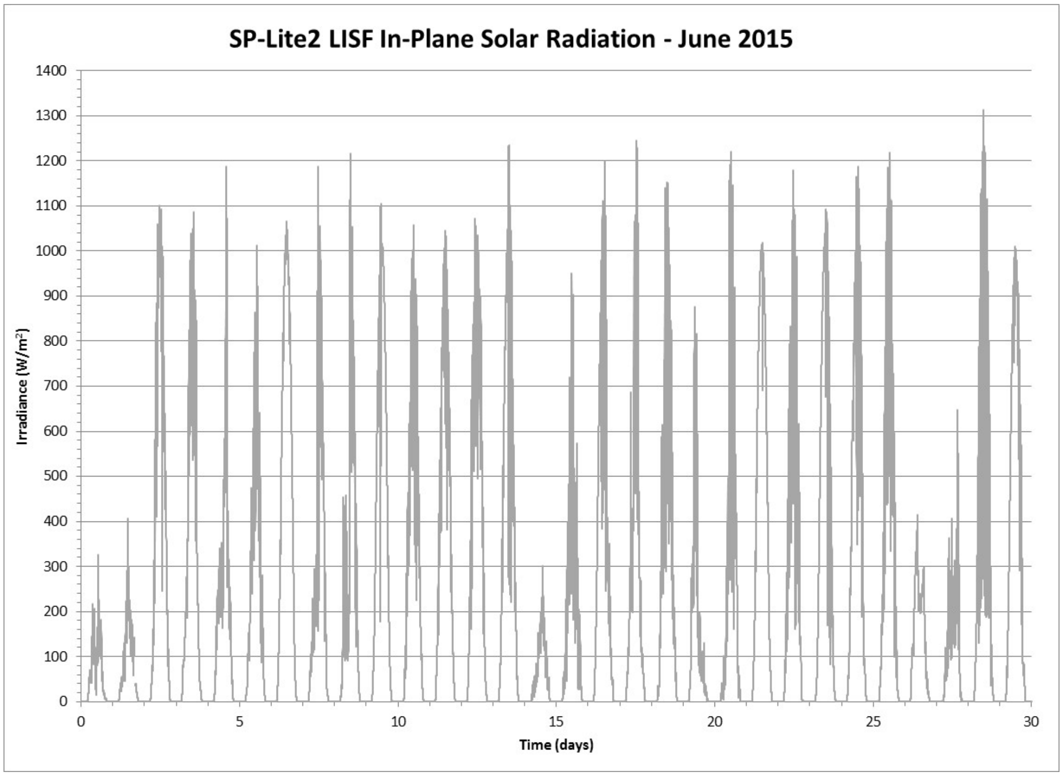

Figure 196 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for June 2015

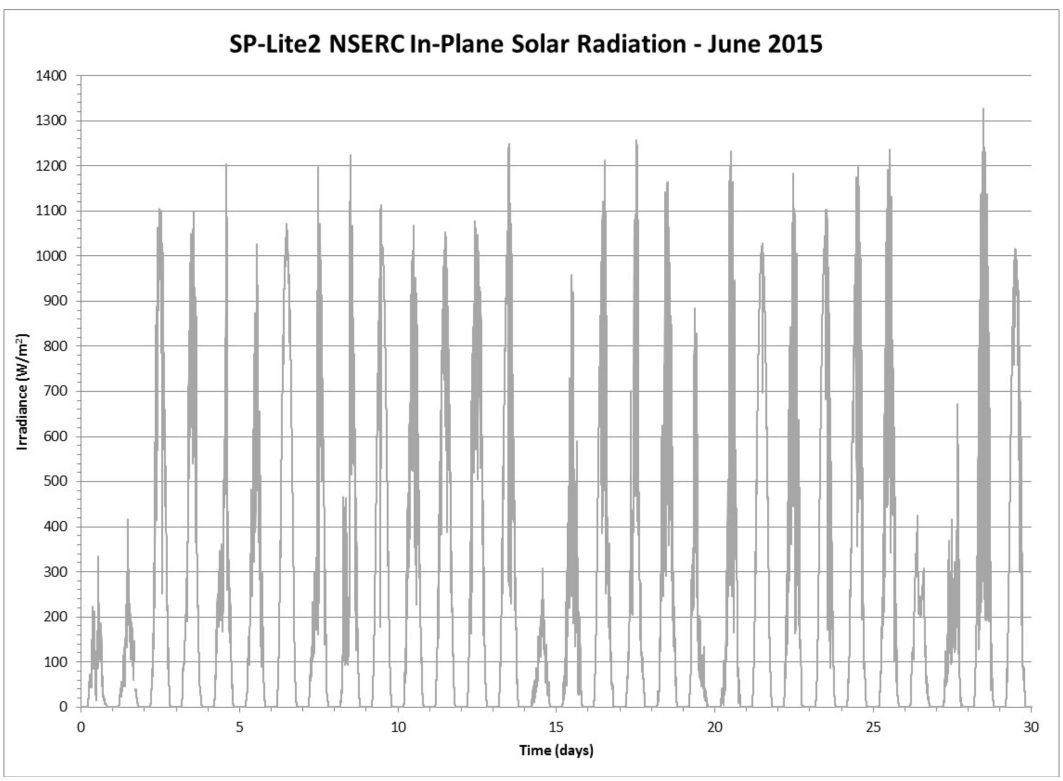

Figure 197 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for June 2015

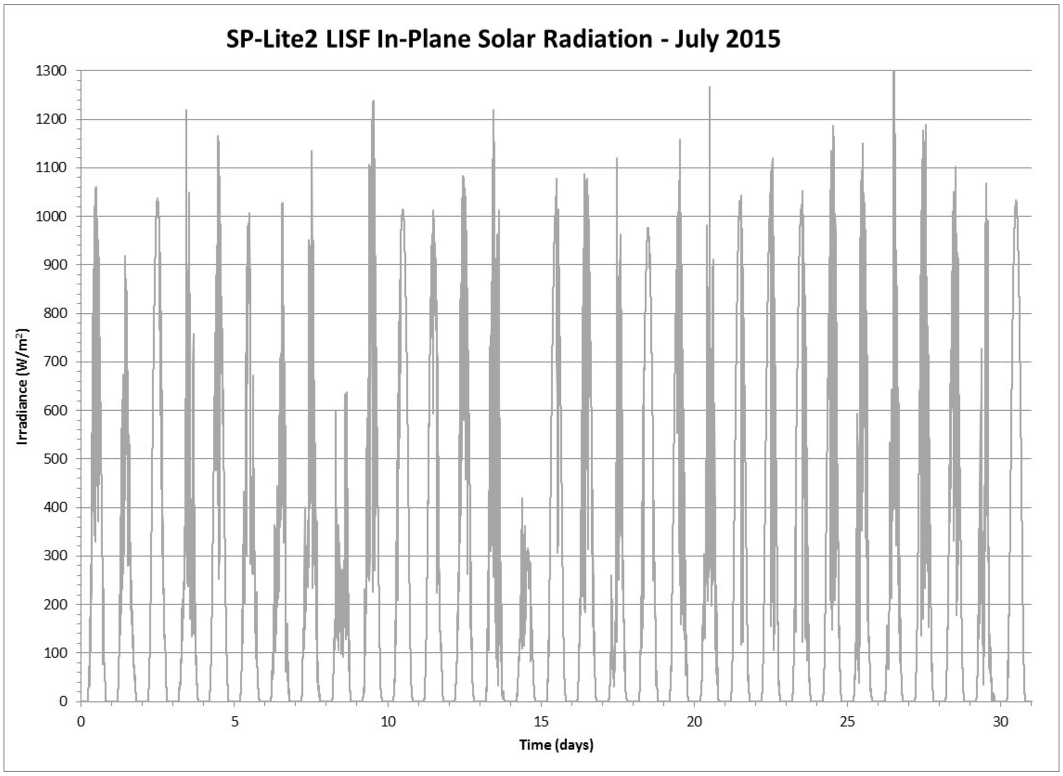

Figure 198 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for July 2015

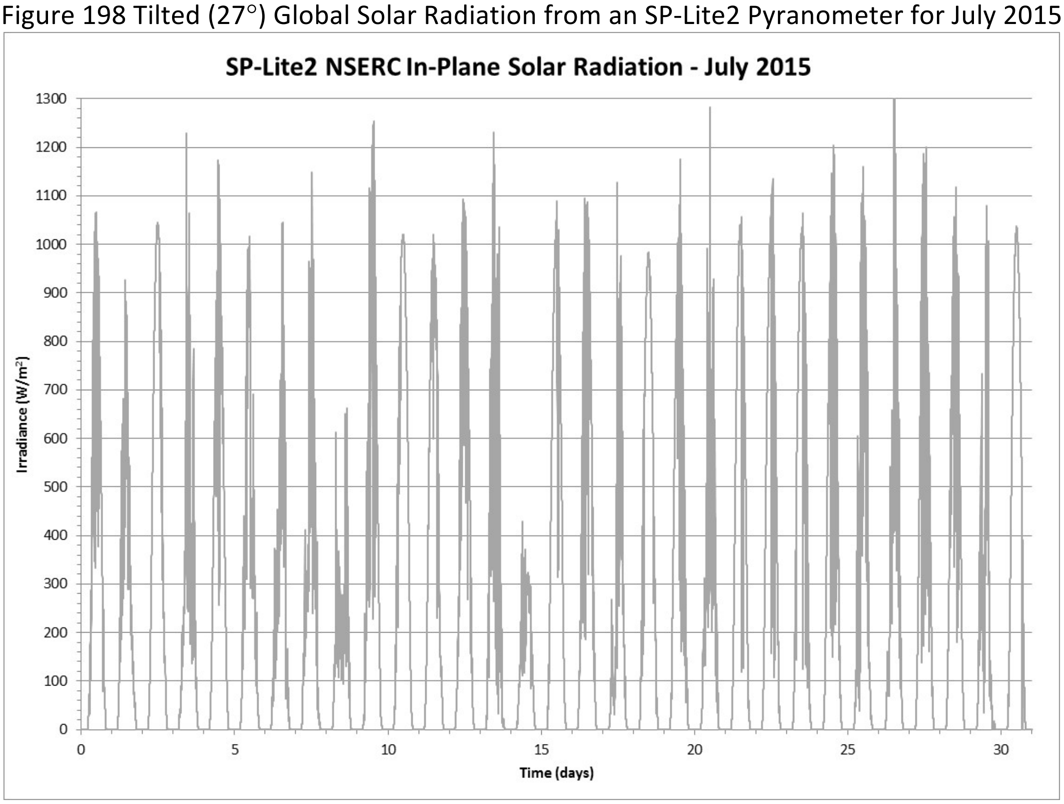

Figure 199 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for July 2015

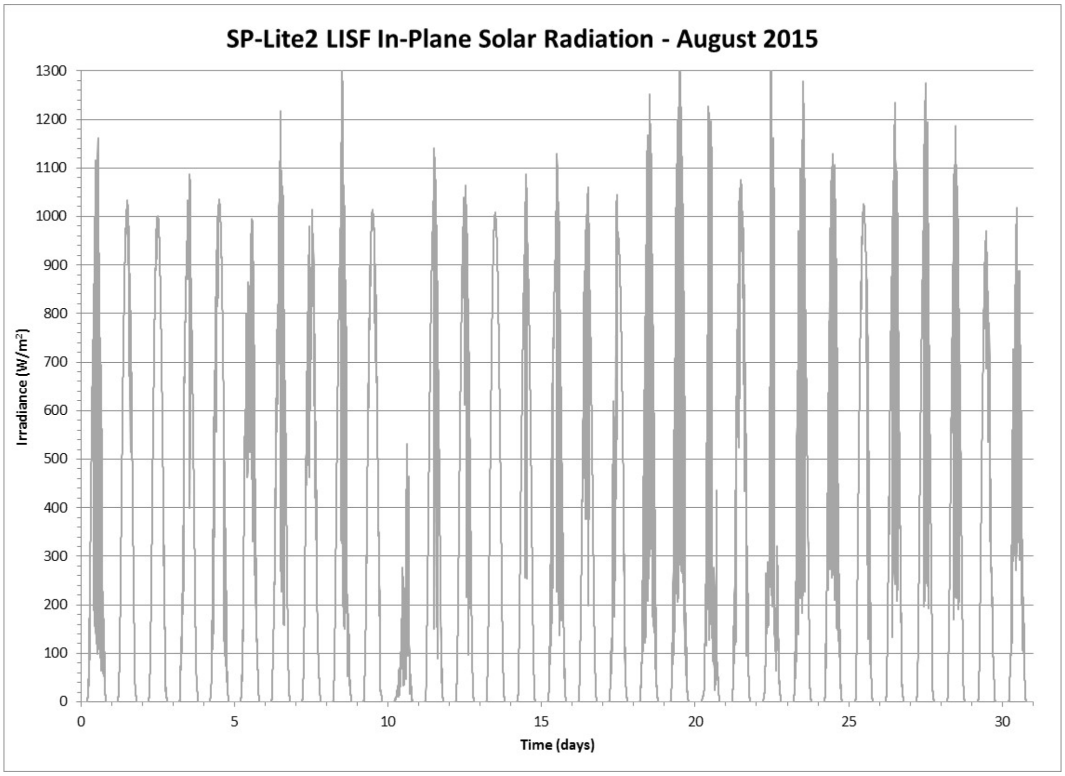

Figure 200 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for August 2015

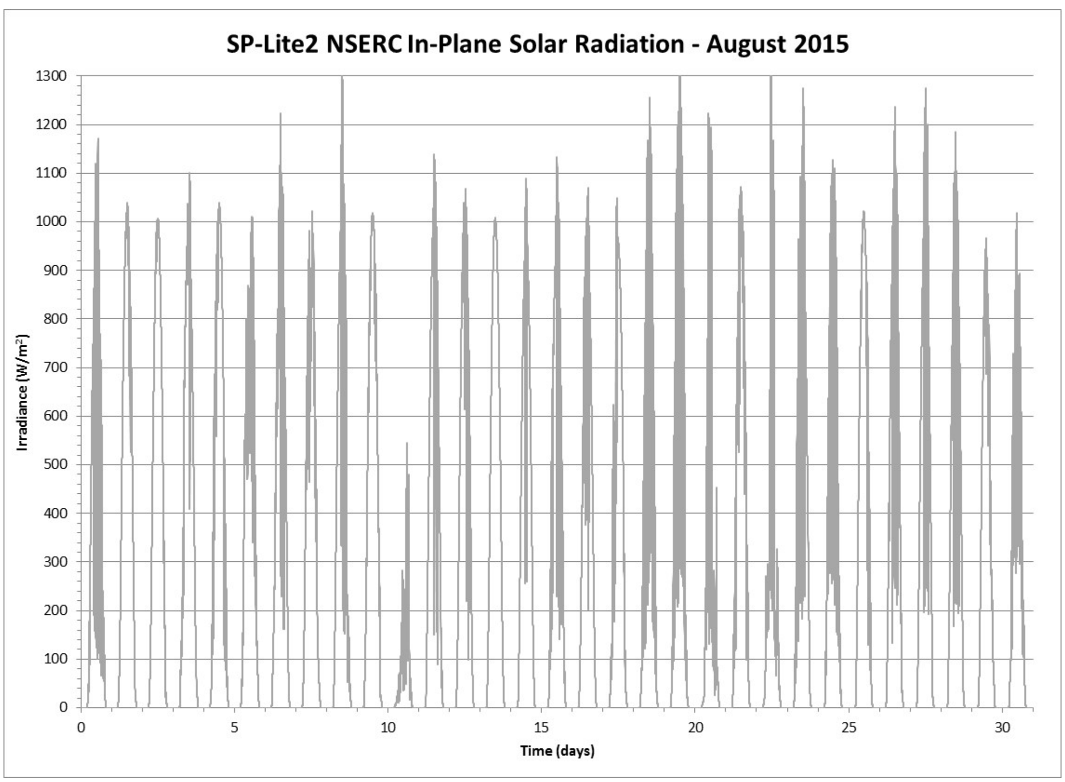

Figure 201 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for August 2015

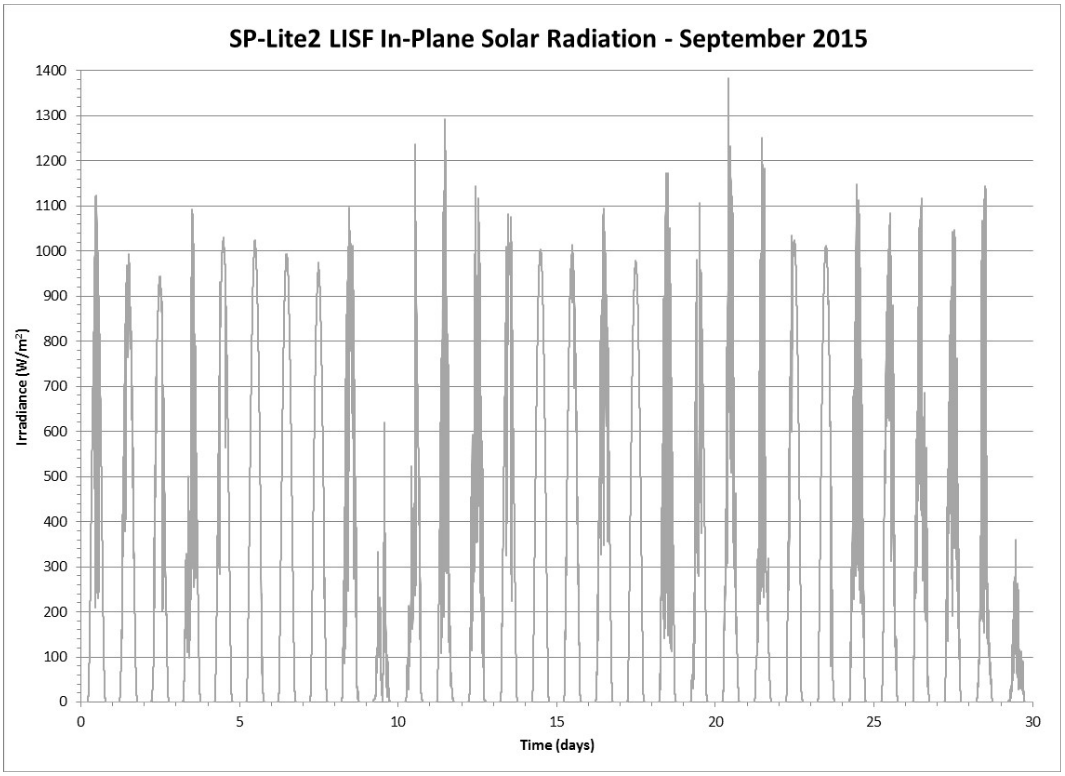

Figure 202 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for September 2015

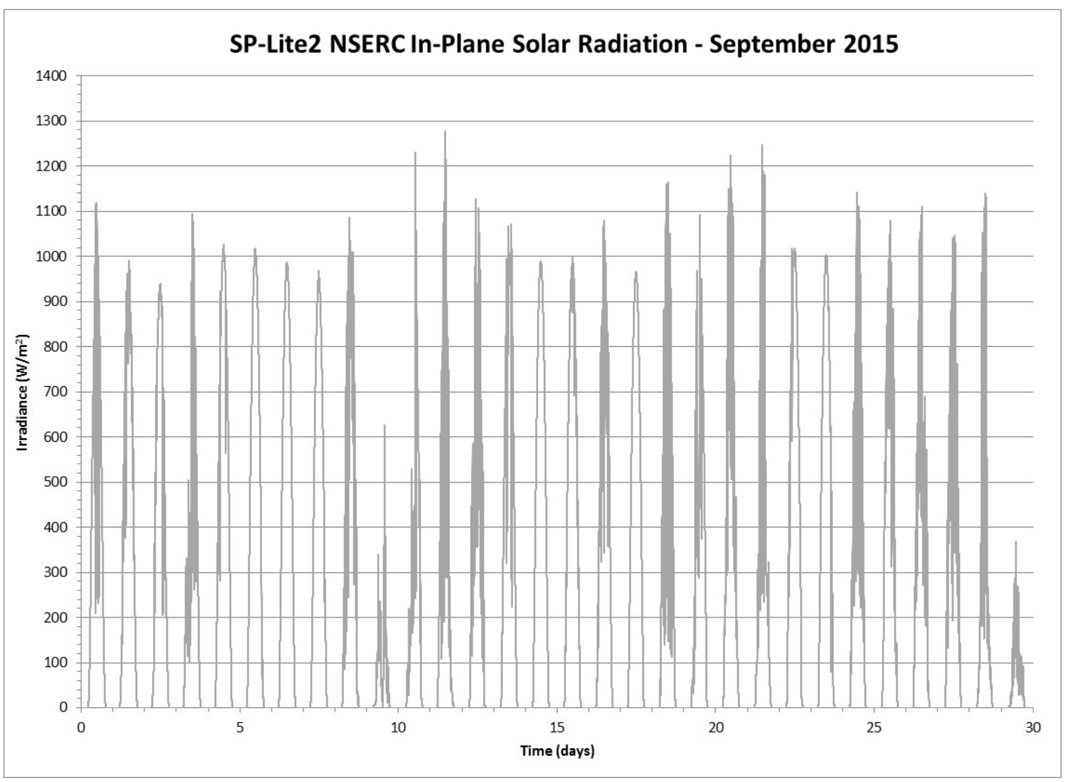

Figure 203 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for September 2015

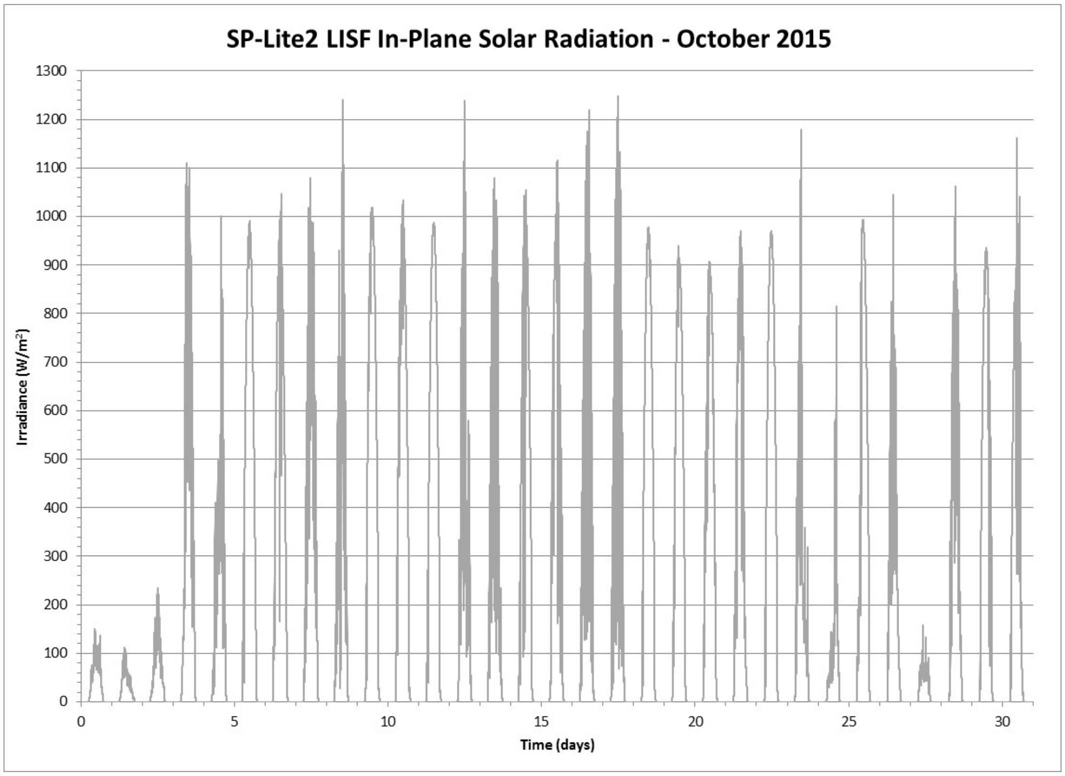

Figure 204 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for October 2015

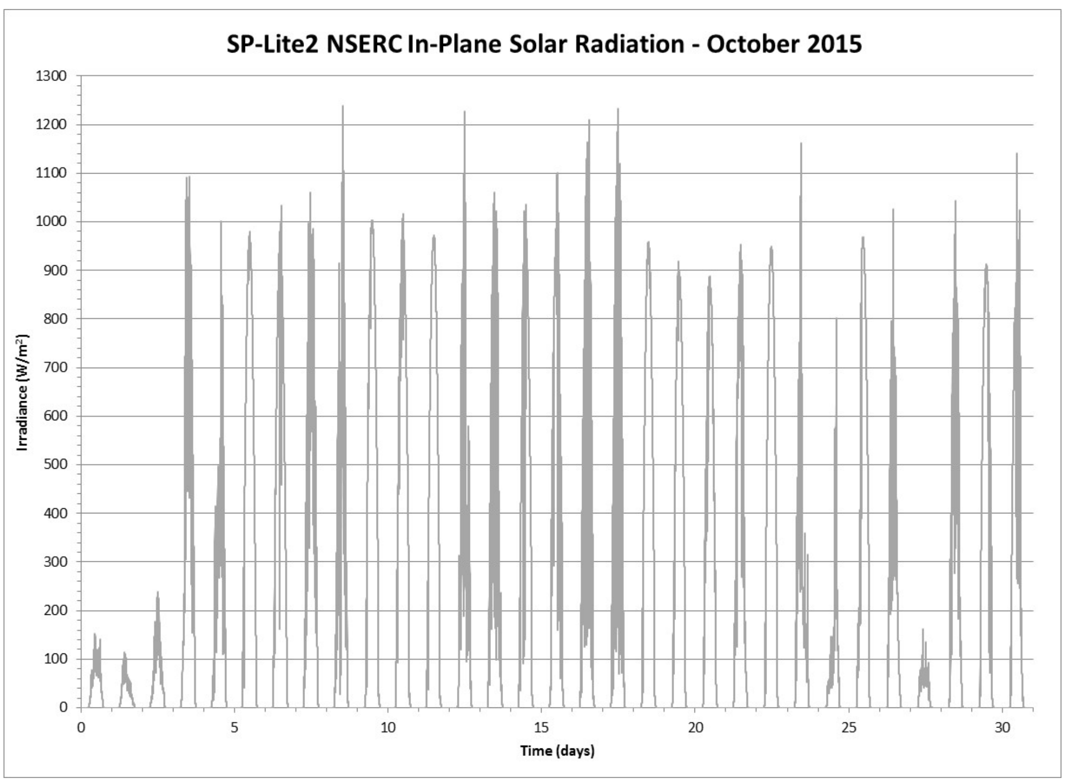

Figure 205 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for October 2015

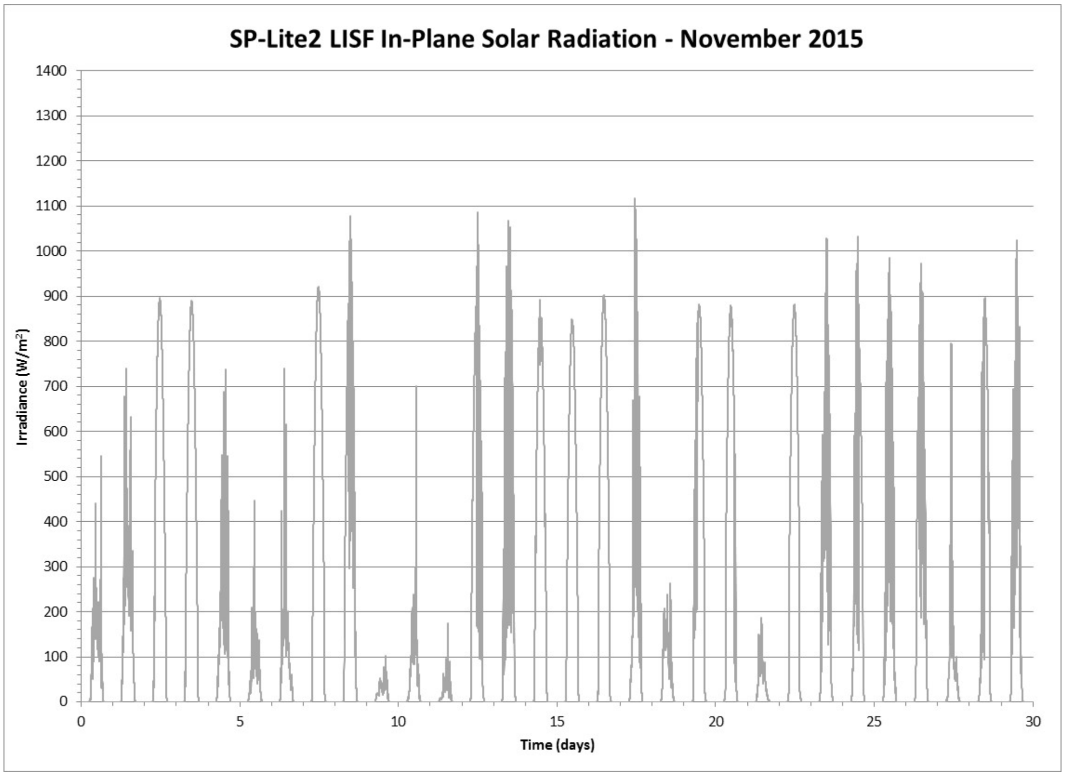

Figure 206 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for November 2015

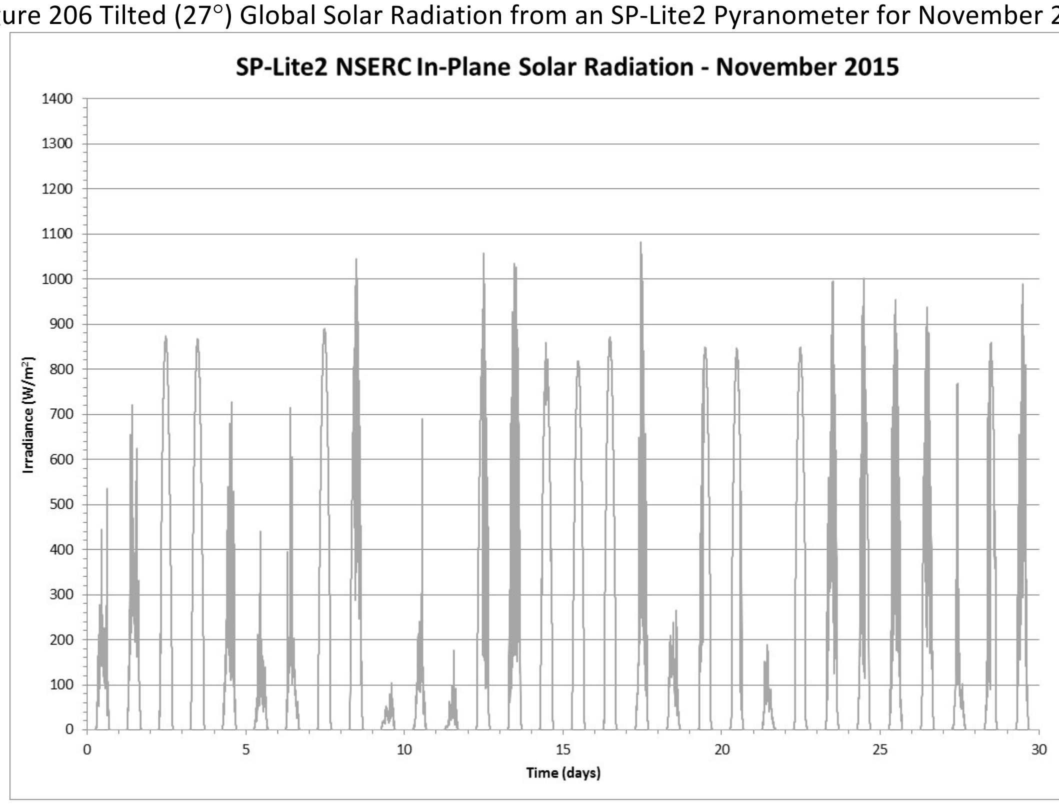

Figure 207 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for November 2015

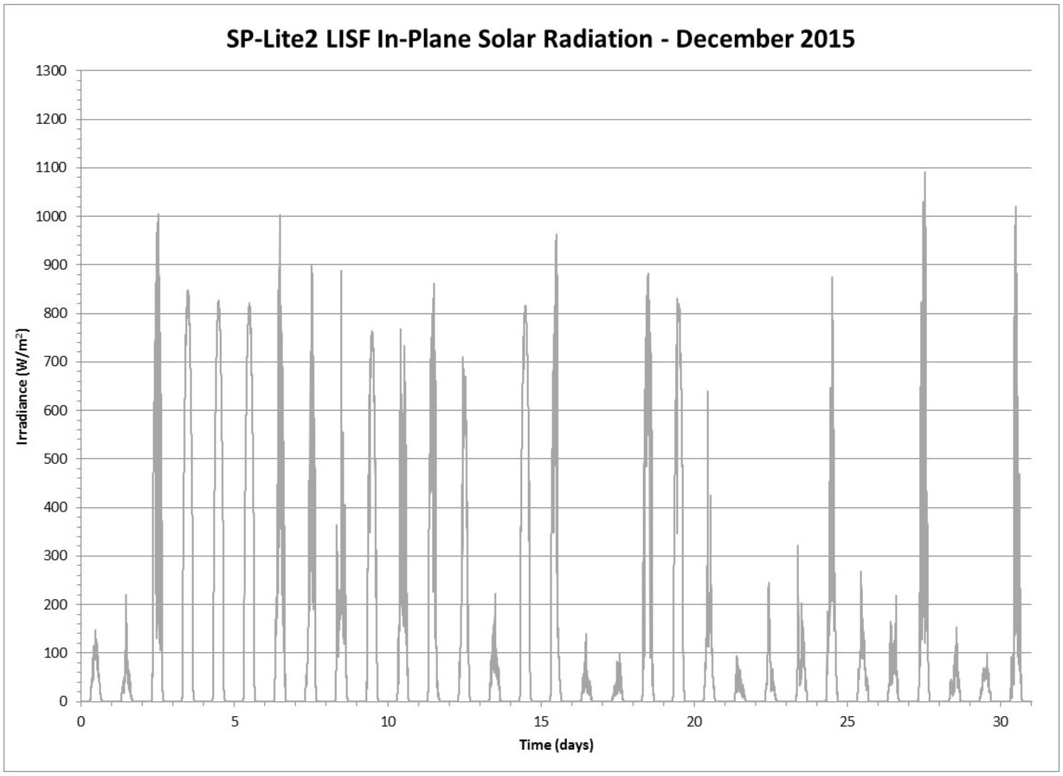

Figure 208 Tilted (27°) Global Solar Radiation from an SP-Lite2 Pyranometer for December 2015

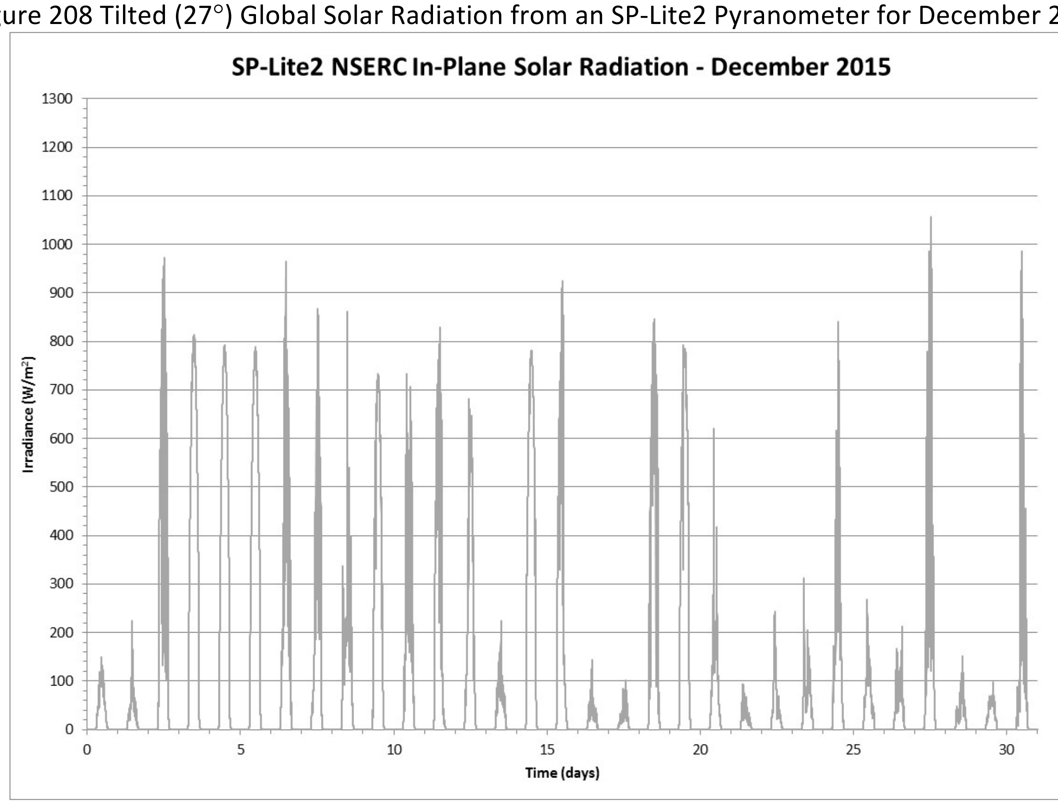

Figure 209 Tilted (23°) Global Solar Radiation from an SP-Lite2 Pyranometer for December 2015

References

ASTM D6176-97 (reapproved 2008), Standard Practice for Measuring Surface Atmospheric Temperature with Electrical Resistance Temperature Sensors.

ASTM G183-05, Standard Practice for Field Use of Pyranometers, Pyrheliometers and UV Radiometers.

ASTM D3631-99 (reapproved 2007), Standard Test Methods for Measuring Surface Atmospheric Pressure.

American National Standard ANSI0ANS-3.11-2005, "Determining Meteorological Information at Nuclear Facilities", American Nuclear Society, 2005.

Heiser, J., Instrument Calibration Plan and Procedures, Brookhaven National Laboratory Report BNL-99891-2013-IR, February 16, 2013.